INFLUENCE OF DIFFERENT CEREAL GRAINS ON BROILER PERFORMANCE, CARCASS COMPOSITION, AND QUALITY

BY

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1986

ACKNOWLEDGMENTS

The author wishes to express his appreciation to his major advisor, Dr. J.E. Marion, for his guidance, strong direction and support of a program of coursework and research providing depth of understanding in both nutrition and food science.

Appreciation is expressed to Dr. Richard D. Miles who taught the author the real meaning of good research and whose genuine concern, and great effort and skill with manuscript revision made the successful completion of this manuscript possible.

The author is also indebted to the other committee members, Dr. R.H. Harms, Dr. D.M. Janky, and Dr. R.H. Schmidt, for their guidance and effort on his behalf. Special thanks go to the professors of the University of Florida Poultry Science Department for their continual guidance and assistance with this and other research conducted.

Additional gratitude is extended to Dr. Ben Mather and Dr. Scott Woodward whose extended hand of friendship was greatly appreciated and whose advice throughout the author's research and job search were of immeasurable value.

Sincere appreciation is expressed to the author's parents, Dr. and Mrs. Gordon E. Bell, for their support and to his friend, Dr. Manly Boss, whose encouragement helped to make the return to school

less unsettling. Finally, and most importantly, the author wishes to extend his deepest appreciation to his wife, Mary, and to his children, Heather, Laurel, Miranda and Jeremy, for their support during this project. It is to them that he dedicates this work.

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August, 1986

Chairman: James E. Marion
Major Department: Animal Science

Studies were conducted to evaluate the feeding value and effect on carcass composition and quality of new varieties of alternate cereal grains which grow well in the Southeast.

The first five studies were conducted for 21 days in electrically heated battery brooders. Substituting triticale for 25, 50, or 100% of the corn in isocaloric diets containing either 21 or 23% crude protein resulted in performance equal to corn at both protein levels. The birds fed the 100% triticale based diet required 23% protein to achieve optimal growth and efficiency.

Increasing choline, vitamin E and certain other micronutrients did not improve the growth rate and feed efficiency observed from feeding triticale or corn based diets.

Corn, triticale, wheat and milo based diets supplemented with either corn oil or animal fat were evaluated in a 49-day floor pen

study designed to more closely simulate commercial growing conditions. Diets supplemented with corn oil (CO) supported better growth rates than with animal fat (AF). Chick performance (within each fat source) with triticale, wheat or milo based diets was equal to, or greater than, the corn based diet. The birds were processed at 49 days and the effects of diet on several carcass quality and compositional factors were evaluated. Dietary grain source did not alter carcass dressing yield, fat pad yield, fat pad lipid level, liver yield or cooked flavor of the carcass.

Shank pigmentation levels were affected by grain source. Corn based diets produced the highest dominant wavelength and excitation purity while triticale produced the least.

Whole body proximate composition was also altered by diet. Birds fed corn or triticale based diets with CO had higher carcass protein levels than those fed triticale or milo with AF. The liver lipid levels were highest for birds fed corn and milo based diets and lowest for triticale and wheat based diets.

Birds fed triticale, wheat or milo based diets had more saturated and monounsaturated and less polyunsaturated abdominal fatty acids than corn fed birds.

CHAPTER I
INTRODUCTION

The high cost of transporting grain, poultry, and poultry products has influenced the trend towards centralization of poultry operations within relatively small geographical areas, sometimes in close proximity to grain sources. The egg industry is currently experiencing a discernable shift back to the Midwestern U.S. to avoid the considerable expense of shipping grains.

If Florida is to continue to profitably produce poultry, increased production (acreages) of cereal grains must occur to provide an economic alternative to the expensive freighted corn. Typically, grain (corn) production in Florida and Georgia has not increased because of problems associated with the climate. Recently, however, agronomists have developed new plant varieties of wheat, triticale, milo, and tropical corn that prosper in the Florida soil and climate and offer promise of providing a local source of cereal grains. These grains have the added advantage of being suitable for double cropping with soybeans and are relatively resistant to aflatoxin which has been a problem in the Southeastern U.S.

Considerable research has been conducted in the past to evaluate wheat, milo, and triticale as an alternate source to corn as cereal grains for poultry, but a review of the current literature reveals few research reports with the newer varieties of these grains for use in

broiler feed formulation. Even fewer data are available on the effects that these grains may have on the fat and body composition, quality, and keeping characteristics of poultry meat.

Currently milo and wheat are utilized in layer and, to a minor extent, in broiler diets when the prices of these feedstuffs drop 5% or more below the price of corn. However, little interest exists in the older varieties of triticale. The research data reported in this dissertation will provide new information on formulation of broiler feeds with alternate cereal sources and address the effect of feeding these grains on the carcass quality characteristics of broiler chickens. This new information may continue to stimulate increased interest in the utilization of these cereal grain sources and may further stimulate the currently expanding production of these crops for even greater economic benefit to Southeastern states.

The substitution of an alternate cereal source could reduce the cost of broiler feeds by as much as $5.00 a ton when used as a corn replacement (Marion, 1984; Ouart et al., 1984). This could save the poultry industry millions of dollars in reduced feed costs, thus making competition in the national market more feasible for poultrymen from Florida and other Southeastern states.

The principle objectives of this research are as follows:

1) Compare the dietary contributions of four alternate cereal sources (grain sorghum 'milo,' Florida 301 and 302 soft red winter wheat, Beagle 82 triticale) with three corn sources (Pioneer 304C tropical corn and two commercially available yellow corn crops).

2) Determine the formulation parameters for utilization of these regionally grown (SE states) cereal grains sources for broiler feed as determined by body weight gain and feed conversion values.

3) Assay the growth and efficiency response of chicks to two protein levels when fed diets containing triticale substituted for 25, 50, or 100% of the corn in the diet.

4) Compare corn oil and animal fat as a supplemental fat source for formulation with the alternate grain sources as assayed by body weight gains and feed conversion in broilers.

5) Assay the effects of pelleting on broiler performance with triticale and corn due to differences in grain density.

6) Determine the growth and feed efficiency response of broilers to the addition of higher than recommended (NRC, 1977) levels of choline, vitamin E, and other micronutrients.

7) Determine the relationship between the fat source and grain source combinations on the proximate composition of the carcass and on the moisture and lipid concentrations of the liver.

8) Conduct sensory evaluations of the flavor of baked carcasses from broilers fed alternate grains to determine if any differences in flavor attributable to diet are detectable.

9) Compare the influence of wheat, milo, triticale, and corn on broiler shank pigmentation.

10) Assay the effect of dietary grain source on the fatty acid composition of broiler abdominal fat.

CHAPTER II
LITERATURE REVIEW

The information in the literature on various sources of grain for poultry feed is extensive and represents contributions from nearly every major poultry research institution.

A review of the current literature reveals contrasting reports on substitution of milo for corn in poultry feed formulations. Many researchers have been successful in substituting milo for corn. As early as 1934, Payne reported that milo could be substituted for yellow corn in chick rations. Baelum and Petersen, according to Petersen (1969), showed comparable results in a broiler feeding trial using diets of 40% corn, milo, wheat, barley, or oats. Ozment _et al._ (1963) showed equally good results when feeding a diet containing milo as when feeding yellow corn. Damron _et al._ (1968) also showed that the feeding of certain varieties of milo did not depress feed intake or body weight gains. In other studies poorer performance was sometimes encountered. Vavich _et al._ (1959) showed milo to be limiting in lysine. Kemmerer and Heywang (1965) compared the nutritive value of five varieties of sorghum grains with corn and found that two of the sorghums were equal to corn while three were inferior when substituted on a gram for gram basis. They further reported that, after diets were balanced for protein and energy through addition of fish flour and cottonseed oil, all milo sources

were inferior to corn. Other researchers (McClymont, 1952; Harms et al., 1958a, 1958b; Chang and Fuller, 1964; Petersen, 1969) also demonstrated that the substitution of milo for corn in broiler feed resulted in reduced performance. Many nutritionists suspected that the variation in performance for various milo varieties could be attributed to the presence of the darkly pigmented tannin in the grain seed coat of the bird resistant milos. Chang and Fuller (1964) reported growth depression in birds fed tannic acid at the .5-2% level to be related linearly to the tannin content of the diet. They noted that, when metabolizable energy (ME) and protein levels were equalized, growth retardation and increased liver lipid levels occurred in direct proportion to the level of tannin contained by the various sorghums. Petersen (1969) cited Baelum and Petersen as showing marked growth depression and reduced feed efficiency in birds fed diets containing 1% tannin. Petersen (1969) also obtained similar results. In contrast, other researchers (Damron et al., 1968; Stephenson et al., 1968; Rayudu et al., 1970) reported a poor correlation between the seed coat color and the feeding value of milo.

Waldroup et al. (1967) showed that the substitution of wheat or milo for corn on a pound for pound basis resulted in significant increases in weight gains in turkeys. Potter et al. (1971) also reported comparable performance from turkeys fed wheat and milo.

Studies by some researchers (Stephenson et al., 1971; Armstrong et al., 1973) have shown a variability in the amino acid content and availability in milo, suggesting possible supplementation to correct deficits and to increase performance of chicks fed diets containing

milo. Researchers are not in complete agreement as to which are the limiting amino acids in sorghum. Studies by Chang and Fuller (1964), Fuller et al. (1967), Connor et al. (1969) and Rayudu et al. (1970) have shown that supplemental methionine or choline (methyl donors) could ameliorate the growth depression from high tannic acid in the diet. Elkin et al. (1978) studied high tannin (HT) and low tannin (LT) varieties of sorghum and concluded that, for the HT sorghum, both methionine and lysine are equally limiting. They were able to show a growth response from the addition of methionine when lysine was supplemented simultaneously to the diet. For the LT sorghums they determined lysine to be the first limiting amino acid and methionine to be the second. Stephenson et al. (1971) tested 24 varieties of sorghum in an effort to determine the limiting amino acids. They observed considerable variability between varieties, where methionine content ranges from .154 to .242%. Lysine and threonine were also shown to vary widely. To further complicate matters, the availability of the amino acids varied even more than the total content of amino acids. Proline was an extreme example which ranged in availability from 19.4 to 93.4%. Stephenson et al. (1971) failed to determine the limiting amino acids but concluded that the variability was probably genetic and suggested cooperation between the nutritionist and plant geneticist to determine the value of a sorghum to be used. Vavich et al. (1959) compared the amino acid profiles of high and low protein sorghums and determined that the biological value of the protein in the high protein sorghum was less than that for the low protein sorghum. When they compared the essential amino acid (EAA) contents

of the sorghums to whole egg protein, they concluded that both sorghum proteins were low in arginine and lysine. Isoleucine and leucine were in considerable excess in the high protein sorghum. The low protein sorghum compared favorably with wheat and corn. Lysine was shown to dramatically improve the biological value of the low protein variety (Vavich *et al.*, 1959). Although lysine and methionine are the two amino acid supplements most likely to produce positive results, it seems apparent that the extreme variability in nutritional quality of sorghum requires the nutritionist to obtain an accurate nutrient analysis of the specific sorghum to be fed prior to formulating any diets. The concept of adjusting nutrient composition precisely when feeding alternate cereal grains was suggested by Marion *et al.* (1984) and Charles (1985) and has been the basis of a study by Armstrong *et al.* (1973) with milo; Fernandez *et al.* (1974) and Marquez and Avila (1974) with triticale; Nelson *et al.* (1980) with wheat; and Luis *et al.* (1982) with millet, milo and corn.

Florida 301 and 302 wheat are two varieties recently developed at the University of Florida Agricultural Research and Education Center in Quincy, Florida, for use in the Southeast (Barnett and Luke, 1980; Barnett *et al.*, 1986). Both are soft red winter wheats which have excellent resistance to leaf rust and powdery mildew; diseases which are problems for other varieties of wheats grown in Florida (Barnett and Luke, 1980; Barnett *et al.*, 1986). The Florida 302 variety requires about ten more days to mature than the 301 wheat which is early maturing. Multiple cropping and minimum tillage systems are widely used in North Florida (Barnett and Luke, 1980), and the two

wheat varieties are well suited for use in these systems as early spring plantings in rotation with soybeans.

Primarily due to its high price, wheat has traditionally been considered to be principally a human food, but recent economic influences have caused some downward fluctuation in price, thus increasing the interest in wheat as a feedstuff for chickens (Marion, 1984). The use of wheat as a major cereal component in poultry rations has been increasing recently and this use has implications for Florida and other Southeastern states: wheat may reduce the cost of feed and can be double cropped in the Southeast, thus reducing the need to freight in Midwestern corn (Ouart et al., 1984).

Parsons and Ridlen (1984) estimated the value of wheat as 95% that of corn for layer rations. Potter et al. (1971) determined the relative value of wheat for feeding turkeys to be 93.4% of that for corn. Currently wheat is being brought into use in least cost formulated poultry diets when it is priced 80-90% that of corn. This means an approximately equal cost per calorie for wheat and corn (Ouart et al., 1984). At this price, savings can range from approximately $1.00-5.00 per ton of finished feed and this can potentially save the Southeastern poultry industry millions of dollars (Marion, 1984; Ouart et al., 1984).

Marion et al. (1984) conducted a series of trials comparing performance of broilers fed diets containing wheat, corn, milo or triticale. They determined that, when the diets were isocaloric and contained equal concentrations of amino acids, 21-day body weights and feed efficiency of wheat fed birds were equal to or superior to

corn. Bragg and Akinwande (1973) also reported that a high protein wheat could, when supplemented with lysine, serve as the sole source of protein for broiler breeder pullets. Fernandez et al. (1974) noted that feeding wheat and corn resulted in similar growth, and these grains were superior to rye. Waldroup et al. (1967) showed that the substitution of wheat or milo for corn on a pound for pound basis resulted in significant increases in growth rate for turkeys. The successful use of wheat as a grain source in layer diets was demonstrated by Bragg et al. (1971), who concluded that wheat diets supplemented with lysine could provide normal growth and development for White Leghorn pullets. Studies at the University of Florida's research station have also shown that feeding wheat to pullets resulted in growth and development equal to that resulting from feeding corn (Christmas et al., 1985b, 1985c). Christmas et al. (1985c) fed two commercial types of laying chicks diets which contained either corn, milo, triticale, or wheat as the sole dietary grain source. Upon placing the birds in the laying house, those reared on all corn diets were fed either all corn or the other three grains substituted at 25 or 50% of the grain source. Those reared on the cereal grains were fed all corn layer diets. There was little difference in growth due to diet, but the birds reared on wheat or triticale produced a greater number of eggs than those raised on corn or milo. Christmas et al. (1985a) concluded that locally produced small grains appeared to be suitable for rearing pullets or for substitution in laying diets.

Other researchers have observed that the feeding of wheat slightly reduced performance. Shariff et al. (1983) determined that weight gain of chickens and quail fed triticale was greater than gain for those fed Durum wheats and hard wheats in their trial. Baelum and Petersen, according to Petersen (1969), reported the results of a broiler feeding trial showing that, when various grains were fed at the 40% level, the birds fed corn, sorghum, and barley diets had equivalent weights while those fed the wheat and oat diets gained 3 and 4% less, respectively. Petersen (1969) conducted a study in which he fed wheat, corn, sorghum, sorghum plus tannin, barley, and oats. He determined that the chickens fed the corn or oat based diets achieved the highest gains while those fed the wheat or sorghum based diets were 2-3% lighter in weight. Cuca and Avila (1973) reported a reduction in rate of egg production when wheat or triticale replaced 100% of the milo protein in layer diets. These researchers suggested that the decreased egg production was probably due to a deficiency of one or two amino acids in the diet or possibly due to a deficiency of linoleic acid which they noted was deficient in wheat and triticale. Kim et al. (1976) also observed a drop in egg production and egg size when the hens were fed wheat or triticale based diets.

The conflicting reports on the performance of birds fed wheat diets illustrate the need for more accurate nutrient analysis before formulating with these alternate grains (Nelson et al., 1980).

The metabolizable energy (MEn) of a feedstuff is the primary factor needed to determine the replacement of that feedstuff for corn (Nelson, 1984). The National Research Council's (NRC, 1977) suggested

value for the MEn of wheat is 83% of that for corn. Recently, Dale and Fuller (1984) have suggested that the published MEn value for corn (3430 Kcal MEn/Kg) in NRC (1977) is too high and they calculated it to be approximately 3080 Kcal MEn/Kg, which makes the replacement value for wheat to be 89% of corn. Dale and Fuller (1984) concluded that true metabolizable energy adjusted for nitrogen (TMEn) content of grains is a more accurate indicator of the actual amount of utilizable energy in a feedstuff and estimated the TMEn value for wheat to be from 3520-3580 Kcal TMEn/Kg of dry matter or about 91.3% of the value for corn. Nelson (1984) reported the results of an earlier review of the use of wheat in poultry feeds where he found a wide variation in ME values which ranged from 2,640 to 3,762 Kcal/Kg of dry matter. This further emphasizes the importance of obtaining accurate analysis of feedstuffs before diet formulation, particularly for experimental studies.

Much of the variability in the data which exist on performance of birds fed wheat can be attributed to the considerable variation which occurs in the amount of protein present in wheat. Protein content of wheat can vary from 10 to 17% on a dry matter basis (Nelson, 1984). The average amino acid digestibility for wheat was determined to be 93% while that for corn was 97% (Nelson, 1984). Kirby et al. (1978) and Nelson et al. (1980) found no differences in the digestibility of amino acids in hard red spring wheats grown in three different areas of the country but they did observe differences in protein content.

Differences in wheat protein quality due to certain limiting individual amino acids has been the subject of considerable study.

Bragg and Akinwande (1973) indicated that wheat protein was limiting in lysine, threonine, and valine when fed to Cornish males and that lysine supplementation was necessary with wheat based diets for broiler breeder pullets. March and Biely (1972) conducted a series of three trials with White Leghorn hens and found that, regardless of the previous dietary treatment, birds fed wheat diets supplemented with .2% lysine produced more eggs than those fed unsupplemented diets. Increased egg weights and better feed efficiency were also observed. No response was obtained from the supplementation of methionine, although the researchers noted that birds fed the unsupplemented diets were poorly feathered. Jeppesen and Grau (1948) demonstrated that wheat protein contained adequate concentrations of arginine, leucine, methionine, and tryptophan to support chick growth but found lysine supplementation improved growth. Strain and Piloski (1972) compared the nutritional value of various wheat and barley samples for feeding chicks from 3 to 10 weeks of age. In their trials, barley supported better growth than the wheat. These researchers suggested that the higher energy levels of wheat resulted in decreased feed intake and this resulted in lysine deficiency. When the wheat diets were supplemented with additional lysine, growth was restored. The supplementation of wheat diets containing low protein with combinations of methionine, leucine, threonine, arginine, valine, and isoleucine produced no significant additional response over the wheat plus lysine diet. Threonine supplementation did result in a slight but consistently better growth rate which indicates that threonine was possibly the second limiting amino acid in wheat for chicks. The diet

containing wheat plus lysine and threonine gave the best feed to gain ratio of all the diets tested while the wheat plus lysine, threonine, and valine gave slightly improved weight gains in broiler breeder chicks over the wheat plus lysine and threonine alone. From these studies it can be concluded that the most limiting amino acid is lysine, followed by threonine and valine. Bragg and Akinwande (1973) suggested the use of the level of dietary lysine to control the early growth rate of broiler breeder chicks.

Shariff et al. (1983) studied the individual components of the carbohydrate complex of wheat and compared them to those found in other cereal grains including corn. Total available carbohydrate values were calculated as the sum of reducing sugars, nonreducing sugars, and soluble and insoluble starch fractions. Soft wheat had 64.95% total available carbohydrates which was not significantly different from the other wheat and triticale values. The alpha-amylase inhibition for the soft wheat, one Durum wheat, and the two triticales, was significantly lower than for the other grains tested.

The albumin fraction of wheat contained a large number of protein components capable of inhibiting alpha-amylase in poultry (Shainken and Birk, 1970; Silano et al., 1973, 1975). Shyamala and Lyman (1964), Mikola and Kirsi (1972), Camus and Laporte (1973), and Petrucci et al. (1976) reported the presence of a trypsin inhibitor (protein) component in wheat. Marci et al. (1977) reported that continuous intake of these wheat albumin fractions depressed growth rate and caused hypertrophy of the pancreas in chickens fed a high starch diet.

Shariff et al. (1983), after extensive characterization of the carbohydrate nature of cereal grains and after bioassays with chickens, quail, and flour beetles, concluded that the alpha-amylase activity of cereal grains has little, if any, true effect on the growth of the chicken. They surmised that this was because the chicken's gastrointestinal tract was efficient in inactivating the inhibitor.

Triticale is a small grain crop produced by crossing Durum wheat with rye and then treating the resulting sterile hybrid with colchicine to produce a hexaploid (Barnett et al., 1982; Morey et al., 1982; Barnett, 1984). Intentional hybridization of wheat and rye to produce triticale dates back to a description published by Wilson in 1876, according to O'Mara (1953), who credits the resultant triticale as being the first "fixed" hybrid, allopolyploid, that was recognized as one. These earliest crosses were relatively infertile and unavailable for feed use (O'Mara, 1953). Fortunately, genetic improvements have created new triticale cultivars that have real potential for feed, food, and forage (Morey et al., 1982). Triticale matures early enough for double cropping with soybeans, sorghums and other summer crops, thus enhancing its suitability for production in the southeastern United States where there is considerable demand for a winter grown grain which can be efficiently double cropped (Barnett et al., 1982; Morey et al., 1982). An additional advantage is that triticale is better able to endure unfavorable environmental conditions, is more resistant to certain diseases than wheat, and has an advantage in sandy, acid soils (Morey et al., 1982).

Beagle 82 triticale was developed jointly by the University of Georgia Coastal Plain Experiment Station in Tifton, Georgia, and by the University of Florida Agricultural Research and Education Center in Quincy, Florida. Unlike many other triticale varieties, Beagle 82 contains very little trypsin inhibitor or xylan hemicellulose (which can cause sticky droppings) and therefore is better suited for livestock and poultry feeding (Morey et al., 1982; Barnett, 1984).

Beagle 82 produces about 5% aneuploid progeny which will produce off-type plants regardless of all present efforts to maintain purity (Morey et al., 1982). Many factors may contribute to the considerable variation in nutritional quality observed by researchers (Charles, 1985). Villegas et al. (1970) studied 25 crosses or varieties of triticale and found that the protein content varied between 10.1 and 19.3% and that lysine content varied from 2.32 to 3.42 g per 16 g of nitrogen. These differences seem reflected by the substantial variation in growth responses of poultry reported during the past several years and point again to the need for precise nutrient analysis of the specific grain to be used before accurate formulation can be achieved (Charles, 1985).

Many researchers have been successful in formulating diets with triticale and have observed acceptable weight gains and feed efficiencies from birds fed triticale based diets. Sell et al. (1962) showed no growth differences in starting chicks when triticale was substituted for wheat on a weight basis. Bragg and Sharby (1970) reported that wheat could be partially or totally replaced in broiler chick diets by triticale without affecting growth. Shariff et al.

(1983) fed two triticale and eight wheat varieties to chicks and quail, determining that the triticales were superior to Durum wheats and hard wheats in supporting growth. Halvorson et al. (1983) reported a slight improvement in growth for turkeys when triticale was substituted for corn and suggested a high protein content in triticale was responsible for the improvement.

Triticale based diets have also been shown to produce desirable results when fed to layers. Kim et al. (1976) compared corn, wheat, and triticale for feeding commercial leghorn hens and found comparable performance from the birds fed wheat and triticale based diets. Weber et al. (1972) compared egg production from hens receiving either sorghum, triticale, or wheat and found that the egg production for the triticale fed birds was as high or higher than the production from birds fed the other grain types.

In an earlier study, Fernandez et al. (1973) showed that laying diets containing up to 85% triticale appeared to lack certain amino acids, resulting in depressed performance. Reduced growth observed in some studies from the feeding of triticale has been positively attributed to a deficiency of one or more amino acids in the diet. Sell et al. (1962) and Bragg and Sharby (1970) identified lysine as the most limiting amino acid in triticale. Sell et al. (1962) reported that, when triticale was substituted for wheat on an isonitrogenous basis, growth depression and reduced feed efficency were observed, suggesting poorer amino acid balance. In contrast, Knipfel (1969) produced evidence, while studying the protein quality

of triticale, that the protein efficiency ratio (PER) of triticale was similar to that of rye and better than the PER of wheat.

Fernandez and McGinnis (1974) conducted a series of experiments to determine the effect of feeding high levels of triticale to young chicks. Comparable levels of corn or rye were fed for comparison. They observed that chicks which were fed diets containing 55% triticale were only slightly smaller than chicks fed a comparable corn diet. The birds fed rye grew even more slowly than the triticale or corn fed birds. When the dietary level of triticale was increased to 73%, growth depression was more pronounced and no differences in body weight existed between the triticale or the rye fed birds. Lysine supplementation of the 73% triticale diet improved growth. This indicated that lysine may have been limiting in the diet. According to Charles (1985), Avila and Cuca published evidence of a growth response to lysine but not methionine in diets that contained either a mixture of soybean meal and triticale or in which all of the protein was supplied by triticale.

Charles (1985) observed reduced growth in chicks which were fed a diet containing 70% triticale. He also observed significant differences between the growth response of birds fed two different cultivars of triticale. The cultivar with the lowest threonine level produced the poorest growth. Methionine was apparently not the limiting amino acid in these diets but it was suggested that the growth depression resulted from inadequate concentrations of other amino acids (like threonine). Lysine and threonine were also suggested by Fernandez and McGinnis (1974) to be the first two

limiting amino acids in triticale. Several researchers have shown that in triticale based diets, threonine is the second limiting amino acid for swine (Shimada and Cline, 1974; Erickson et al., 1978, 1979).

Marquez and Avila (1974) determined that tryptophan, valine, and methionine were not limiting in triticale based broiler starter diets and that the addition of threonine resulted in increased growth. McGinnis (1976) confirmed this observation by improving growth rate through the addition of threonine.

In general, the use of triticale for feeding chicks has been found to be satisfactory only when protein quality considerations are observed (Sell et al., 1962; Bragg and Sharby, 1970; Fernandez and McGinnis, 1974; Marquez and Avila, 1974). Allee (1974) has also suggested that triticale can be successfully substituted for corn, wheat, barley, or sorghum when proper consideration is given to protein content. It appears that successful formulations must include adequate amounts of supplemental lysine and threonine to provide a proper amino acid balance. The digestibility of the amino acids in triticale is excellent and does not seem to be a significant factor in formulation. Nelson (1984) determined that the 94% amino acid digestibility of triticale was better than the digestibility for oats and barley but slightly below that for corn (97%).

The nature of the carbohydrates in a grain source may also influence the suitability of that source for feeding chickens. McNab and Shannon (1975) felt that triticale was a better carbohydrate source for the chicken than either wheat or rye. Shariff et al. (1983) calculated the total available carbohydrate for triticale as

the sum of the reducing sugars, nonreducing sugars, and soluble and insoluble starch fractions. They determined that the total available carbohydrate fraction (65.84%) in the two triticale varieties tested was not significantly different from the totals found in eight varieties of hard and soft wheats. The presence of alpha-amylase inhibitors in cereal grains has often been credited for decreasing their feeding value. The two triticales, one normal soft wheat, and one of the Durum wheats were found to have significantly less alpha-amylase inhibitor activities than the other grain varieties sampled by Shariff et al. (1983).

No significant differences between the amylose levels of any of the grains tested were observed and the amylopectin/amylose ratios remained about the same. This indicated that the branched and straight chain starch composition of the various wheats, triticale and barley were similar (Shariff et al., 1983). Shariff et al. (1983) concluded that the starch content of cereals has the most significant effect on their nutritional value for fowl, followed by the crude protein and pectin content. They determined that alpha-amylase inhibitor did not affect the growth of chickens or quail and concluded that the chicken's gastric digestion is very effective in inactivating alpha-amylase inhibitor.

The performance of chicks fed triticale based diets depends not only on the amino acid content and carbohydrate quality, but on the energy levels used in formulation. Marion et al. (1984) observed reduced growth in broiler chicks fed triticale based diets when a value of 3080 Kcal ME/Kg was assigned to triticale. They suggested

the need for more accurate amino acid and energy values for formulating diets with triticale. Dale and Fuller (1985) and Fuller and Dale (1986) conducted studies designed to determine the TMEn of Beagle 82 triticale and concluded that it was between 3350 and 3360 Kcal TMEn/Kg dry matter. Nelson (1984) reviewed studies by Dale and Fuller, Sibbald, Tenesaca and Sell, Muztar et al., and Halvorson et al. and determined that the ME and TME value for triticale were 97 and 91% of those for corn, respectively.

Mineral availability in feedstuffs is becoming more important in poultry feeding. Aw-Yong et al. (1983) assayed the availability of Ca, P, Mg, Mn, Zn, and Cu in 10 samples of corn, 3 sample of barley, 11 samples of wheat and 1 sample of triticale. Calcium availability was found to be higher in the triticale than for any of the wheat, barley, or corn varieties tested. Phosphorus availability was higher for the triticale than for the corn, but about average compared to the wheats and barleys. Magnesium availability was higher for the triticale than for the wheat, barley, and corn averages while Mn availability was lower than the corn average but higher than the wheat and barley averages. Availability of Zn in triticale was equal to corn and higher than for the wheats and barleys, while Cu availability was higher for the triticale than for either the corn or wheat and barley averages. Overall, with the exception of Mn, the availability of the assayed minerals in triticale was comparable or superior to those found in corn.

Shimada et al. (1974), Marion et al. (1984), and Charles (1985) have noted that acceptability problems sometimes exist with the

feeding of triticale. Charles (1985) suggested that this may be due to possible contaminants such as ergot, while Shimada et al. (1974) and Marion et al. (1984) suggested that palatability may be the problem.

The total performance and value of alternative cereal grains when substituted for corn cannot be entirely predicted on the basis of nutrient composition and weight gains or feed conversion alone. Other considerations, such as flavor, protein content, fat composition, liver fat deposits, and the stability of carcass fat against hydrolysis and oxidation, must all be evaluated when considering the relative values of a substitute cereal grain in broiler feed formulation.

Dietary factors can affect the liver lipid levels in the birds as was demonstrated by Jensen et al. (1974) who reported significantly lower liver fat in hens fed wheat than in those fed corn. They concluded that dietary factors other than energy appeared to be involved in liver fat metabolism. Jensen et al. (1976) further investigated this claim and found that hens fed corn, triticale, or milo deposited more liver fat than those fed barley, oats, or rye.

The grain source used in the diet can influence the overall fat composition of the feed. Ward and Marquardt (1983) showed that the grain source in the diet of chickens influenced the nature (saturation, chain length, and fatty acid composition) of the dietary fat and that this in turn had an effect on the fat absorbed by the birds. Corn contains higher levels of oil than milo, and corn oil has higher levels of the polyunsaturated linoleic acid than milo oil.

These differences are reflected in the fatty acid pattern of diets into which these grains are incorporated (Bartov and Bornstein, 1976a). The synergistic relationship created by the addition of source of unsaturated fats into more highly saturated fats has been previously reported (Renner and Hill, 1961; Young, 1961; Lewis and Payne, 1966). These researchers recognized that the addition of the unsaturated fats significantly enhanced the normally poor absorption of palmitic and stearic acids. Young and Garrett (1963) then showed that the presence of oleic acid and linoleic acid (to a lesser extent) enhanced the absorption of the saturated fatty acids. Lewis and Payne (1966) conducted a series of digestibility studies and determined that the inclusion of 5% soybean oil in beef tallow could increase the digestibility from 75% to 87%.

The fat composition of the overall diet is influenced by the grain source and by the added fat. Hulan et al. (1984) conducted two experiments to test the effects of adding poultry grease, beef tallow and pork lard, singly or in combination, to broiler diets. They concluded that fat source had little differential effect on total performance but that the combination of the fats gave improved growth and had a profound effect on the fat composition of the overall diet.

Differences in the fat composition of the diet, brought about by differences in grain source and supplemental fat source, will in turn influence the amount and composition of the fat deposited in the carcass. The problem of excessive fatness in broilers above a certain weight is also of economic importance and can be influenced by the grain and type of supplemental fat fed. Petersen (1969) reported that

milo produced the most fat deposition compared to corn, barley, wheat, and oats. Jensen (1973) showed a higher level of fat deposited from milo and corn than from the other grains. Kim et al. (1976) showed body fat depot stores in layers were less with corn diets, most abundant with wheat, and intermediate with triticale. When Fraps (1943) decreased calorie to protein (C:P) ratio in broiler diets by substituting casein, cottonseed meal, or other proteins for corn, he was able to show a decrease in carcass fat deposition. The level of fat inclusion in the diet can also affect the amount of fat deposited in the carcass. The correlation between increased dietary fat and increased carcass lipid concentration has been widely documented (Fraps, 1943; Donaldson et al., 1956; Marion and Woodroof, 1966; Mickelberry et al., 1966; Rinehart et al., 1975).

The ratio of calories to protein (C:P) in the diet is one of the most important factors affecting the growth of the bird and the composition of the carcass produced (Fraps, 1943; Donaldson et al., 1956; Bartov et al., 1974a; Edwards and Denman, 1975; Twining et al., 1975; Bartov and Bornstein, 1976a, 1976b, 1979; Griffiths et al., 1977). In general, reducing the C:P ratio lowers the fat accumulation in the carcass while increasing the ratio raises fat accumulation. Griffiths et al. (1977) reported that the addition of a low quality protein source (feather meal) to a diet with an "optimum" C:P ratio had the same effect on decreasing fat pad weight as did the addition of a good quality protein. The effect of altering the dietary C:P on the carcass composition is rapid (Yoshida and Morimoto, 1970; Thomas

and Twining, 1971; Bartov et al., 1974a). Changes in fatness have been observed as early as 10-14 days after changing the C:P ratio.

The effect of composition of the dietary fat, from grain source and supplemental fat, on the fatty acid composition of the carcass of birds has been demonstrated by many authors (Marion and Woodroof, 1963, 1966; Mickelberry et al., 1966; Lipstein et al., 1970; Salmon, 1973; Salmon and O'Neil, 1973; Bartov et al., 1974b; Webb et al., 1974). Bartov and Bornstein (1974b) showed an increase in the iodine value (percent unsaturation) of carcasses of birds when even small amounts (3%) of vegetable oils were added to diets. In general, the linoleic acid content of the supplemental fat source affects an increase in linoleic acid content of the carcass at the expense of oleic acid. Mickelberry et al. (1966) demonstrated that the feeding of supplemental corn oil increased carcass levels of linoleic acid and decreased levels of oleic and palmitic acid. Animal fat supplementation increased oleic acid levels and decreased palmitic, palmitoleic and linoleic acid levels in the carcass. Bartov et al. (1974b) reconfirmed this by testing a variety of oil sources at different dietary levels and showed a significant linear correlation between the amount of dietary oil and the iodine value of abdominal fat. Also, the concentration of linoleic acid in the diets and in the respective carcass fat was linearly correlated. Chickens synthesize and deposit relatively more palmitic, palmitoleic, stearic, and oleic fatty acids than are usually found in the diet. When the dietary fat levels are low, the carcass concentrations of these saturated fatty acids will increase (Salmon, 1973). Salmon (1973) estimates that the

rate of change of fatty acid composition in the bird provides for a 50% change in 2.4 weeks. Essary and Dawson (1965) and Lipstein et al. (1970) supplied evidence that abdominal fat was most readily altered by the diet.

The amount of fat in the carcass as well as the fatty acid composition of that fat have been shown to alter the resistance of the carcass to lipid oxidation (Klose et al., 1951; Marion and Woodroof, 1963, 1966; Edwards et al., 1973; Salmon and O'Neil, 1973; Bartov et al., 1974b; Bartov and Bornstein, 1976b). Increasing the degree of unsaturation of abdominal fat due to higher levels of soybean oil, or milo, markedly decreased its stability in a study by Bartov and Bornstein (1976b). These researchers noted that the carcasses from broilers with high degrees of unsaturation in their fatty tissues were less stable against oxidative rancidity. This susceptability to rancidity and the reduced solidity of unsaturated carcass fat in these birds can have serious economic implications.

Increasing the fatness of the chicken tends to increase the degree of saturation of the carcass fat and increase its stability and the stability of the meat (Marion and Woodroof, 1966; Bartov and Bornstein, 1976a, 1976b, 1979). Bartov and Bornstein (1979) observed a considerable increase in the degree of saturation of broiler abdominal fat as the birds became fatter. This fattening resulted in a decrease in linoleic acid and corresponding increase in palmitic, palmitoleic, and oleic acids. The higher level of saturated fatty acids appears to be the product of increased lipogenesis brought on by excessive energy levels (high C:P) responsible for the fat condition

of the bird (Bartov and Bornstein, 1976a). Since the birds cannot synthesize the more unsaturated linoleic or linolenic acids, lipogenesis has the effect of increasing the saturation of depot fat (Bartov and Bornstein, 1976a). They found that the increased incorporation of unsaturated fats produced by feeding supplemental vegetable oils could be overcome by the greater quantities of saturated fats synthesized by the bird when the C:P is excessively high. The problem of excessive fatness in broilers can be effectively reduced by lowering the C:P but this in turn increased dietary cost and can create a greater problem by increasing the unsaturated fats in the carcass and thereby rendering it more susceptible to oxidative damage. Oxidative spoilage has been effectively reduced by feeding vitamin E or synthetic antioxidants to the birds prior to slaughter (Webb et al., 1974; Bartov and Bornstein, 1976b).

Dietary grains have been suggested to cause differences in the flavor of cooked chickens. Petersen (1969) reported a distinguishable flavor difference between birds fed milo and birds fed a corn diet and correlated this off-flavor with the presence of tannin in the milo. He conducted a sensory evaluation of carcasses from birds fed various cereal grains and concluded that the grains had no effect on the appearance of the cooked product but that panelists preferred (data were not statistically different) the flavor of carcasses from birds fed oats, barley and corn over those fed sorghum or wheat.

The tannin in some varieties of milo has been implicated as a cause of yolk mottling. Fry et al. (1972) observed mottling associated with the feeding of tannin but noted that it was

significant only when the diet contained at least 2% tannic acid. Potter et al. (1967) reported that when layers were fed tannic acid levels of 1-2% they produced significantly higher levels of yolk mottling. Fry et al. (1972) suggested that feeding of sorghum at levels up to 60% should not produce a detectable increase in yolk mottling.

The research program described here involved investigations with new varieties of alternative cereal grains: Beagle 82 triticale, Florida 301 and 302 wheat, a commercial nonbird resistant variety of milo and Pioneer 304C tropical corn. Because of the recent development of these new grain cultivars, very little research has been conducted with these grain varieties in poultry diets.

The principal objective of this study was to evaluate the alternative cereal grains as feedstuffs for broilers and to assay the effect of feeding different grains and diet combinations on broiler growth, feed efficiency, carcass composition, sensory qualities, and fatty acid composition.

CHAPTER III
COMPARISON OF THE PERFORMANCE OF BROILERS FED PRACTICAL DIETS CONTAINING ALTERNATE GRAINS

Introduction

The renewed interest in newer varieties of small grains as substitutes for corn has predicated a need for more research to establish the influence these newer varieties have on poultry performance. Research with older varieties of these grains is extensive, but data on the new varieties are limited and inadequate. In a series of three earlier trials, Marion *et al.* (1984) compared the growth of broiler chicks fed diets containing Beagle 82 triticale, a nonbird resistant variety of milo, and Florida 301 wheat substituted isocalorically for corn. The diets contained equal levels of lysine and sulfur amino acids, and 3124 Kcal ME/Kg. They observed that growth rates were best with the wheat diets followed by corn, milo and triticale and concluded that amino acid and energy values available for incorporating these new varieties of grains into broiler diets needed considerable refinement before maximum feed utilization could be obtained.

The following two experiments were conducted to contribute to this refinement of formulation parameters for utilizing these regionally grown cereal grains for use in broiler feeds. Marion *et al.* (1984) had suggested that the 3124 Kcal ME/Kg used in their

experiments was the reason for suboptimal growth. Experiments #1 and #2 were designed to determine the effect of increasing the energy levels of the diets to 3200 Kcal ME/Kg as recommended by the NRC (1977), thus slightly increasing the calorie:protein (C:P) ratio, a factor shown to greatly affect chick performance (Donaldson et al., 1956).

Materials and Methods

Two experiments were conducted with day-old Cobb feather sexable broiler chicks. In the first experiment, five experimental diets were fed which contained Beagle 82 triticale, Florida 301 wheat, Pioneer 304C tropical corn, a locally grown commercial field corn from the 1984 crop, and a commercial Midwestern corn from the 1983 crop (Table 3-1). The diets were formulated to be isonitrogenous and isocaloric (Table 3-2). Experiment #2 was a replicate of Experiment #1 with the exception that a sixth treatment containing Florida 302 wheat (Table 3-3) was added. Table 3-4 gives the nutrient composition of the grain sources.

At one day of age, the chicks were randomized and placed in electrically heated Petersime batteries on raised wire floors. Four males and four females were placed in each pen and each experimental treatment consisted of eight pens. Pen assignments were designed to insure that treatment groups were equally represented in each of the six levels of the battery. Three birds in each pen were introduced to the watering system by dipping their beaks in the water. Feed was first provided on paper towels, and feed level in the troughs was

TABLE 3-1
Composition of the diets
(Experiment #1)

Ingredient*	83 Corn	84 Corn	Tropical corn	301 Wheat	Beagle 82 triticale
Corn	53.00	53.00	53.00	-	-
Wheat	-	-	-	53.63	-
Triticale	-	-	-	-	55.51
Soy (48.5%)	37.89	37.89	37.89	35.50	32.50
Limestone	1.11	1.11	1.11	1.07	1.18
Dical Phos.**	1.72	1.72	1.72	1.68	1.68
Salt	.40	.40	.40	.40	.40
Vit-Min.***	.50	.50	.50	.50	.50
DL-Methionine	.18	.18	.18	.22	.27
Corn Oil	5.20	5.20	5.20	7.00	7.90
Lysine	-	-	-	-	.06

* Ingredient levels expressed as g/100 g of diet.

** Contains 22% Ca and 18.5% P.

*** Standard University of Florida chick micronutrient premix (Table 4-2).

TABLE 3-2
Calculated nutrient contents of the diets
(Experiments #1 and #2)

Nutrient*	83 Corn	83 Corn	Tropical corn	301 Wheat	302** Wheat	Beagle triticale
Protein	23.04	23.04	23.04	23.60	23.60	22.99
Lipid	7.60	7.60	7.60	8.08	8.08	9.17
Calcium	.89	.89	.89	.90	.90	.90
Total Phos.	.69	.69	.69	.70	.70	.70
Arginine	1.66	1.66	1.66	1.64	1.64	1.44
Cys. + Meth.	.93	.93	.93	.93	.93	.93
Threonine	.93	.93	.93	.83	.83	.85
Lysine	1.33	1.33	1.33	1.31	1.31	1.33
Tryptophan	.30	.30	.30	.30	.30	.31
MEn (Kcal/Kg)	3200	3200	3200	3200	3200	3200

* Nutrient values calculated and expressed as g/100 g of diet except where noted.

** Florida 302 wheat was used only in Experiment #2.

TABLE 3-3
Composition of the diets
(Experiment #2)

Ingredient*	83 Corn	84 Corn	Tropical corn	301 Wheat	302 Wheat	Beagle triticale
Corn	53.00	53.00	53.00	-	-	-
Wheat	-	-	-	53.65	53.65	-
Triticale	-	-	-	-	-	54.78
Soy (48.5%)	37.88	37.88	37.88	35.50	35.50	33.30
Limestone	1.11	1.11	1.11	1.05	1.05	1.08
Dical Phos.**	1.72	1.72	1.72	1.68	1.68	1.68
Salt	.40	.40	.40	.40	.40	.40
Vit-Min.***	.50	.50	.50	.50	.50	.50
DL-Methionine	.19	.19	.19	.22	.22	.25
Corn Oil	5.20	5.20	5.20	7.00	7.00	7.97
Lysine	-	-	-	-	-	.04

* Ingredient levels expressed as g/100 g of diet.

** Contains 22% Ca and 18.5% P.

*** Standard University of Florida chick micronutrient premix (Table 4-2).

TABLE 3-4
Values used to calculate diets

Nutrient*	Yellow corn	Nonbird resistant milo	Soft red winter wheat	Beagle 82 triticale
Protein	8.80	10.70	11.90	12.50
Lipid	3.80	2.60	1.35	1.55
Calcium	.02	.04	.05	.06
Total Phos.	.28	.30	.31	.32
Arginine	.50	.41	.60	.63
Cys. + Meth.	.35	.34	.37	.35
Threonine	.39	.36	.28	.37
Lysine	.24	.24	.34	.42
Tryptophan	.09	.08	.12	.16
MEn (Kcal/Kg)	3432	3370	3190	3080

* Nutrient values calculated and expressed as g/100 g of diet except where noted.

maintained at approximately the 5/8 full level through the duration of the experiment. Birds in both experiments were individually weighed at 21 days of age and total pen feed consumption was determined. The data from both experiments were subjected to analysis of variance and significant differences were determined by Duncan's Multiple Range Test (Steel and Torrie, 1960) using computer programs available in the Statistical Analysis System (SAS, 1982).

Results and Discussion

The feeding of three corn sources, Beagle triticale, and Florida 301 wheat in diets formulated to provide 3200 Kcal ME/Kg resulted in no significant differences in body weights for any of the treatments within Experiment #1 or for Experiment #2 which included Florida 302 wheat (Table 3-5). Chicks fed the Pioneer 304C tropical corn, the Beagle 82 triticale, and the two wheat varieties grew as well or better numerically than birds fed the two commercial corn sources.

In these two experiments, the triticale fed birds grew as well as did the corn fed birds in contrast with the results obtained by Sell et al. (1962), Fernandez and McGinnis (1974), and Marion et al. (1984) who observed a mild growth depression in birds fed triticale. The good growth observed in birds fed triticale supports the data from studies by Bragg and Sharby (1970), Halvorson et al. (1983), and Shariff et al. (1983) who reported positive results in growth and feed efficiency from the feeding of this small grain. The reported variations in performance support the need suggested by

TABLE 3-5
Body weights and feed conversion of broiler chicks fed practical diets containing alternate grains (Experiments #1 and #2)

Grain source	Experiment #1		Experiment #2	
	Body weight (g)	Feed convr. (g/g)	Body weight (g)	Feed convr. (g/g)
'83 Commercial corn	607^{a}	1.35^{abc}	569^{a}	1.42^{a}
'84 Commerical corn	594^{a}	1.40^{a}	565^{a}	1.41^{a}
'84 Tropical corn	597^{a}	1.37^{ab}	570^{a}	1.32^{b}
Florida 301 wheat	601^{a}	1.38^{a}	596^{a}	1.33^{b}
Florida 302 wheat	-	-	581^{a}	1.30^{b}
Beagle triticale	622^{a}	1.31^{c}	580^{a}	1.33^{b}

* Means with different superscripts within a column are significantly different ($P \leq .05$) according to Duncan's Multiple Range Test.

Marion _et al._ (1984) for more refinement in formulating diets with these alternate grains.

The favorable feed efficiency observed in the birds fed triticale based diets in the two experiments was also observed in earlier trials conducted by Marion _et al._ (1984). Favorable feed efficiency is consistently observed from the feeding of triticale and is an indication that the quality of the proteins (Knipfel, 1969) and carbohydrates (Shariff _et al._, 1983) in the grain are good and that no antinutritional factors are exerting a significant influence (Morey _et al._, 1982; Shariff _et al._, 1983).

Birds fed wheat based diets grew as rapidly as those fed the other grains. This was expected on the basis of positive reports by Waldroup _et al._ (1967), Bragg and Akinwande (1973), Fernandez _et al._ (1974), and Marion _et al._ (1984).

In Experiment #2 the birds fed the tropical corn were statistically more efficient than those fed the two commercial corn sources. However, the magnitude (6.7%) of this improvement in efficiency was not supported by the data from the first experiment where the feed efficiency of the tropical corn (1.370) matched the average of the efficiencies of the two commercial sources (1.375). It might be concluded that the 5.2% negative change in efficiency for the '83 commercial corn between experiments and the 2% positive change for the tropical corn discredit the 6.7% differences observed. An effort was made to preserve a supply of the tropical corn (in drums) for the second experiment that was as close as possible to the original condition and feeding value used in Experiment #1. It is possible

that the stored corn could have decreased in moisture content, but corn comprises only 53% of the diet in this study (Table 3-3) and the 6.7% decrease in feed required (for the observed improvement in feed efficiency) would have required a drop in moisture of 12.6 g/100 g of diet (assuming moisture content of other ingredients remained unchanged). With number two corn containing only approximately 14-16 g of moisture/100 g of grain, this drop in moisture is unrealistic.

These data indicate that Beagle 82 triticale, Florida 301 and 302 wheat, and Pioneer 304C tropical corn in practical diets can promote performance comparable to that resulting from the feeding of commercial yellow corn when the diets contain the recommended energy level (3200 Kcal ME/Kg).

CHAPTER IV
THE INFLUENCE OF PROTEIN CONCENTRATION, TRITICALE SUBSTITUTION LEVEL, DIETARY BULK, AND SUPPLEMENTAL VITAMINS ON THE PERFORMANCE OF BIRDS FED TRITICALE BASED PRACTICAL DIETS

Introduction

Experiment #1

Numerous studies have been conducted in which triticale was substituted for some portion of the corn in poultry diets (Fernandez *et al.*, 1973; Fernandez and McGinnis, 1974; Goodson and Damron, 1984; Charles, 1985; Christmas *et al.*, 1985c). The results have been variable; some data showed reduced growth while other data indicated acceptable performance from birds fed the triticale. Those researchers who obtained favorable growth generally concluded that triticale could be substituted for some portion, or for all of the corn in the diet, without adversely affecting performance (Weber *et al.*, 1972; Kim *et al.*, 1976; Halvorson *et al.*, 1983; Christmas *et al.*, 1985c). In contrast, substitution limits were proposed by many of those who observed reduced performance when substituting the grain for corn. Fernandez and McGinnis (1974) demonstrated that birds grew almost as well when fed diets in which triticale replaced 55% of the total corn in the diet as when they were fed all corn based diets. However, when these researchers fed diets in which 73% of the total corn in the diet was replaced by triticale they observed a

considerable depression in growth. Goodson and Damron (1984) conducted a trial in which 0, 25 or 50% of the total corn in the diets was replaced by triticale. When 25% of the total corn was replaced by triticale, the birds grew slightly better than they did when fed the other substitution levels. When 50% of the total corn was replaced by triticale, growth was depressed. These data suggested an optimal substitution level existed for triticale in practical corn based broiler diets.

Marion et al. (1984) reported that when the diet contained 3124 Kcal ME/Kg suboptimal growth was observed in birds fed the triticale based diets. In the two previous experiments alternate grain based diets containing 3200 Kcal ME/Kg supported optimal growth with no apparent growth depression from triticale. In the following experiment, an energy level of 3200 Kcal ME/Kg was used. One part of the experiment was designed to further define the relationship between the substitution level of triticale for corn in the diet and broiler performance. Since mixtures of grains often occur in least cost formulations, a better understanding of the feeding value of triticale in mixed grain applications was needed.

A second part of the experiment was designed to investigate the influence of protein level on the performance of birds fed diets containing varying levels of triticale (Table 4-1). Sell et al. (1962), Bragg and Sharby (1970), Allee (1974), Fernandez and McGinnis (1974), Marquez and Avila (1974), and Marion et al. (1984) all suggested a pivotal role for protein quality in determining the success of triticale based diets.

TABLE 4-1
Dietary treatments for Experiment #1

Grain source	% Protein	
100% Corn	23	21
75% Corn:25% Triticale	23	21
50% Corn:50% Triticale	23	21
100% Triticale	23	21

Experiment #2

A reduction in feed intake has been observed in chickens fed triticale based diets (Shimada et al., 1974; Goodson and Damron, 1984; Marion et al., 1984; Charles, 1985). Charles (1985) suggested that possible contaminants such as ergot may be the cause. Shimada et al. (1974) and Marion et al. (1984) speculated that the problem might be related to palatability. The superior feed efficiency observed for birds fed triticale based diets in the previous experiments of this study (Table 3-5) indicated that the problem is not caused by an antinutritional factor which would decrease utilization and reduce efficiency.

A third possibility for the reduced intake of triticale is related to its increased bulk which lowers diet density. A number of researchers have concluded that dietary density affects the growth of birds (Peterson et al., 1954; Mraz et al., 1956, 1957; Pesti et al., 1983). Mraz et al. (1956) reviewed the reports of a number of earlier researchers and concluded that growth was not adversely affected by fiber level at concentrations of approximately 7% but that greater concentrations inhibited growth. Peterson et al. (1954) suggested that the amount of nutrients a chick can consume depends on the density of the diet and not on the total weight of diet consumed. Barnett et al. (1982) reported that Beagle 82 triticale is less dense than either wheat or rye. The increased bulk of triticale based diets may adversely affect the total consumption of feed by requiring longer feeding times to ingest the same quantity of nutrients. This could retard intake in the battery experiments where competition for feeder

space may restrict total feeding time. Jensen <u>et al.</u> (1962) demonstrated that dietary density could affect consumption time.

The experiment to follow was designed to evaluate the effects of dietary restriction and pelleting on the performance and efficiency of birds fed triticale based diets. By restricting intake to 95% of the amount consumed by the *ad libitum* fed birds, total nutrient intake could be equalized for corn and triticale based diets. This would allow a comparison of growth rate without the confounding influence of different intake levels. The second portion of the experiment was designed to determine the effect of pelleting, which alters the density and physical form of the diet, on the performance of birds fed triticale based diets. The diets were optimal for protein (23%) and energy (3200 Kcal ME/Kg) as determined by the previous experiment.

Experiment #3

In an earlier broiler feeding trial with alternate grains conducted at this laboratory, the diets had been mixed with a turkey vitamin-mineral premix (TVMP) instead of the usual chicken vitamin-mineral premix (CVMP) (Table 4-2). At the conclusion of the study, the birds fed the various diets supplemented with the TVMP appeared to be particularly healthy. In the following experiment, corn and triticale based diets supplemented with CVMP or TVMP were fed to broiler chicks to compare the efficacy of the two vitamin-mineral premixes (Table 4-3). Broiler starter diets formulated with triticale and other small grains must compensate for reduced energy levels found in these grains compared to corn by providing more supplemental lipids. The basal triticale diet formulation developed in the first

TABLE 4-2
Composition of the vitamin-mineral premix

Vitamin	Turkey Vit. (TVMP)		Broiler Vit. (CVMP)	Unit*
Vitamin A	6,600		6,600	IU
Vitamin D_3	2,200		2,200	ICU
Vitamin E	11	**	2.2	IU
Vitamin K	2.2	**	4.4	mg
Riboflavin	4.4	**	13.2	mg
Niacin	59.6	**	39.6	mg
Pantothenic acid	13.2		13.2	mg
Choline Chloride	999	**	499	mg
Vitamin B_{12}	22.0		22.0	mcq
Biotin	110.0	**	0.0	mcq
Ethoxyquin	0.0125		0.0125	%
Manganese	60.0		60.0	mg
Iron	50.0		50.0	mg
Copper	6.0		6.0	mg
Cobalt	0.198		0.1980	mg
Iodine	1.1		1.1	mg
Zinc	60.0	**	35.0	mg

* Vitamin concentrations are expressed as their activity per kilogram of finished feed.

** Micronutrients which differ between CVMP and TVMP.

TABLE 4-3
Experimental design for vitamin influence on alternate grains study

Diet	Grain	Vitamin premix
1	Corn	chicken
2	Corn	turkey
3	Triticale	chicken
4	Triticale	turkey

three trials of this study (Table 4-4) contains 53% higher supplemented lipid levels than the corresponding corn basal. This added lipid increases the overall lipid content of the triticale diet to 21% above the level for the corn based diet (Table 4-5). Since high dietary lipid levels have been shown to increase choline requirements (Balloun, 1956) and to be associated with liver lipid levels (Miles et al., 1983; Ruiz et al., 1983) and vitamin E has been demonstrated to aid in the inhibition of lipid oxidation (Calvert et al., 1964; Bartov and Bornstein, 1976b), the higher concentrations of these vitamins in the TVMP might be beneficial to birds fed the triticale based diets containing higher lipid levels. A response to the addition of the TVMP would indicate that the CVMP is limiting in one or more micronutrients necessary for optimum growth with the triticale based diet.

Materials and Methods

Experiment #1

An experiment was conducted with day-old Cobb feather sexable chicks. Broiler starter diets containing Beagle 82 triticale substituted for 0, 25, 50, or 100% of the corn were formulated to provide either 23 or 21 protein concentration (Table 4-6). The diets were designed to provide the same C:P ratio at all levels of triticale substitution within a protein level. The calculated nutrient levels for the basal diets are shown by Table 4-7. Grain nutrient values are listed in Table 3-4.

The birds used in this experiment were housed for 21 days in heated Petersime batteries on raised wire floors as in trial one

TABLE 4-4
Composition of the basal diets

Ingredient*	Corn	Triticale
Corn	52.98	-
Triticale	-	54.78
Soy (48.5%)	37.89	33.30
Limestone	1.11	1.09
Dical Phos.**	1.72	1.68
Salt	.40	.40
Vit-Min.***	.50	.50
DL-Methionine	.19	.25
Corn Oil	5.20	7.97
Lysine	.01	.04

* Ingredient levels expressed as g/100 g of diet.

** Contains 22% Ca and 18.5% P.

*** Standard University of Florida chicken micronutrient premix (Table 4-2).

TABLE 4-5
Nutrient contents of the basal diets

Nutrient*	Corn	Triticale	NRC req.**
Protein	23.04	22.99	23.00
Lipid	7.60	9.17	-
Calcium	.90	.90	.90
Total Phos.	.70	.70	.70
Arginine	1.66	1.44	1.44
Cys. + Meth.	.93	.93	.93
Threonine	.93	.85	.75
Lysine	1.33	1.33	1.20
Tryptophan	.30	.31	.23
MEn (Kcal/Kg)	3200	3200	3200

* Nutrient values calculated and expressed as g/100 g of diet.

** Nutrient recommendations from NRC (1977).

TABLE 4-6
Composition of the experimental diets

Ingredient*	23% Protein		21% Protein	
	Corn	Triticale	Corn	Triticale
Corn	53.00	-	60.82	-
Triticale	-	54.78	-	59.46
Soy (48.5%)	37.88	33.30	31.00	29.00
Limestone	1.11	1.08	1.08	1.03
Dical Phos.**	1.72	1.68	1.84	1.78
Salt	.40	.40	.40	.40
Vit-Min.***	.50	.50	.50	.50
DL-Methionine	.19	.25	.27	.30
Corn Oil	5.20	7.97	4.02	7.50
Lysine	-	.04	.07	.03

* Ingredient levels expressed as g/100 g of diet.

** Contains 22% Ca and 18.5% P.

*** Standard University of Florida chick micronutrient premix (Table 4-2).

TABLE 4-7
Nutrient contents of the diets

Nutrients*	23% Protein		21% Protein		NRC req.**
	Corn	Triticale	Corn	Triticale	
Protein	23.04	22.99	20.40	21.49	23.00
Lipid	7.60	9.17	6.64	8.71	-
Calcium	.89	.90	.90	.89	.90
Total Phos.	.69	.70	.70	.69	.70
Arginine	1.66	1.44	1.44	1.44	1.44
Cys. + Meth.	.93	.93	.93	.93	.93
Threonine	.93	.85	.83	.77	.75
Lysine	1.33	1.33	1.20	1.20	1.20
Tryptophan	.30	.31	.26	.28	.23
MEn (Kcal/Kg)	3200	3200	3200	3200	3200

* Nutrient values calculated and expressed as g/100 g of diet.

** Nutrient requirements are from NRC (1977).

(Chapter III). The birds were weighed at 21 days and total pen feed consumption was determined. Data from this experiment were subjected to analysis of variance and significant differences among treatments were determined by Duncan's Multiple Range Test (Steel and Torrie, 1960) using computer programs available in the Statistical Analysis System (SAS, 1982).

Experiment #2

An experiment was conducted using day-old Cobb feather sexable chicks. Two groups were fed corn-soybean meal and triticale-soybean meal basal mash diets (Table 4-8) *ad libitum*. Two other groups received corn-soybean meal or triticale-soybean meal mash diets equivalent in amount to 95% of the total of feed consumed during the previous 24 hrs by the birds fed the corn mash *ad libitum* diet from the first group. The last two groups received pelleted triticale or corn based diets fed *ad libitum*. Table 4-9 lists the nutrient contents of the basal diets. The birds for this experiment were housed for 21 days in heated Petersime battery cages on raised wire floors as in trial one (Chapter III). The birds were individually weighed at 21 days and the total feed consumption determined. Data were subjected to analysis of variance and significant differences among treatments were determined by Duncan's Multiple Range Test (Steel and Torrie, 1960) using computer programs available in the Statistical Analysis System (SAS, 1982).

Experiment #3

A total of 192 day-old Cobb feather sexable chicks were used for this experiment. The chicks were sexed at one day of age and randomly

TABLE 4-8
Composition of the basal diets

Ingredient*	Corn	Triticale
Corn	53.00	-
Triticale	-	55.57
Soy (48.5%)	37.89	32.50
Limestone	1.11	1.18
Dical Phos.**	1.72	1.68
Salt	.40	.40
Vit-Min.***	.50	.50
DL-Methionine	.18	.27
Corn Oil	5.20	7.90
Lysine	-	.06

* Ingredient levels expressed as g/100 g of diet.

** Contains 22% Ca and 18.5% P.

*** Standard University of Florida chicken micronutrient premix (Table 4-2).

TABLE 4-9
Calculated nutrient contents of the basal diets as compared to NRC requirements

Nutrient*	Corn	Triticale	NRC req.**
Protein	23.04	22.99	23.00
Lipid	7.60	9.17	-
Calcium	.90	.90	.90
Total Phos.	.70	.70	.70
Arginine	1.66	1.44	1.44
Cys. + Meth.	.93	.93	.93
Threonine	.93	.85	.75
Lysine	1.33	1.33	1.20
Tryptophan	.30	.31	.23
MEn (Kcal/Kg)	3200	3200	3200

* Nutrient values calculated and expressed as g/100 g of diet.

** Nutrient recommendations from NRC (1977).

assigned to heated Petersime batteries with raised wire floors where they were housed as in trial one (Chapter III). The wire floors of the cages reduced the possibility of coprophagy which would be expected to increase intake of certain vitamins (like B_{12}) which might be produced by gut flora but not available to the bird except through coprophagy. The four diets consisted of a corn-soybean meal basal with CVMP or TVMP and a triticale-soybean meal basal with CVMP or TVMP (Table 4-3).

The birds were weighed individually at 21 days and feed consumption was determined for each pen. Data from this experiment were subjected to analysis of variance and significant differences among treatments were determined by Duncan's Multiple Range Test (Steel and Torrie, 1960) using computer programs available in the Statistical Analysis System (SAS, 1982).

Results and Discussion

Experiment #1

The averages for the grain treatments across both protein levels showed no significant differences between body weights which could be attributed to triticale substitution level (Table 4-10). Feed efficiency was influenced by the substitution level. The birds utilized the 23% protein all-triticale based diet more efficiently than the 23% protein all corn based diet or the 75% corn:25% triticale diet with 23% protein. Birds also grew more efficiently on the 21% protein all-triticale based diet than on the 75% corn:25% triticale diet at the 21% protein level. Averages for triticale substitution

TABLE 4-10
Effect of protein level on response to different levels of dietary triticale

Grain source	23% Protein		21% Protein		Average	
	B.W.* (g)	F.C.* (g/g)	B.W.* (g)	F.C.* (g/g)	B.W.* (g)	F.C.* (g/g)
100% Corn	569^{a}	1.42^{a}	567^{a}	1.40^{ab}	568^{a}	1.41^{a}
75% Corn:25% Triticale	589^{a}	1.40^{ab}	576^{a}	1.41^{a}	583^{a}	1.41^{a}
50% Corn:50% Triticale	569^{a}	1.38^{abc}	571^{a}	1.39^{ab}	570^{a}	1.39^{a}
100% Triticale	580^{a}	1.33^{c}	558^{a}	1.35^{b}	569^{a}	1.34^{b}

* Means with different superscripts within a column are significantly different ($P \leq .05$) according to Duncan's Multiple Range Test.

level revealed that birds fed the 100% triticale based diet were more efficient than birds fed any of the other triticale substitution levels. Marion et al. (1984) observed a similar improvement in efficiency (compared to corn) from the feeding of all triticale or wheat based diets.

Decreasing the total protein level from 23 to 21% did not cause a significant growth depression for any of the treatments. It did significantly reduce the feed efficiency of the birds fed the 100% triticale based diets from 1.33 to 1.35 g feed consumed/g body weight (Table 4-10). Apparently these birds consumed more of the diet to compensate for the decrease in protein level. An examination of the nutrient contents of the basal diets (Table 4-7) reveals that the threonine concentration dropped 9.4% in the triticale based diet when the protein level was lowered to 21%. This places the total calculated threonine level in the diet at only .02% above the listed minimum level (NRC, 1977). It is probable that the actual available threonine in the diet falls below the amount needed to sustain optimum growth and that threonine may be limiting in the 21% protein all triticale based diet. This conclusion is supported by the literature where threonine has been identified as the second limiting amino acid in diets formulated with triticale (Fernandez and McGinnis, 1974; Marquez and Avila, 1974; McGinnis, 1976; Charles, 1985).

The lysine levels also dropped 9.8% with the lowering of protein level. Lysine is generally considered to be the first limiting amino acid in triticale based diets without lysine supplementation (Sell et al., 1962; Bragg and Sharby, 1970; Fernandez and McGinnis, 1974).

However, lysine was supplemented to both the 23% and the 21% protein all triticale based diets to raise the calculated levels to meet NRC recommendations (NRC, 1977). It is possible that lysine was limiting or co-limiting in the 21% protein all triticale based diet but the 21% protein corn basal diet contained the same calculated level without showing any reduction in efficiency, whereas the concentration in the triticale based diet dropped in threonine relative to the threonine values for the corn based diet.

The data from this study indicate that there was no limit to the level of substitution of triticale for corn in these practical broiler diets when protein levels were adequate. By contrast, feed conversion was poorer in triticale based diets when protein levels were lowered to 21%. The data support the possibility that threonine and/or lysine may become limiting when the protein level is decreased. Future studies should be conducted in which the 21% protein all triticale diets are supplemented with excess levels of lysine, threonine or both to further define the apparent deficiency in the 21% protein all triticale based diet.

Experiment #2

The *ad libitum* fed birds receiving the basal triticale based mash diet grew as well as those receiving the *ad libitum* fed basal corn based mash diet (Table 4-11) and were significantly more efficient in feed utilization. Feed intake was significantly lowered for the triticale fed birds. The reduced feed intake observed with birds fed the triticale based diet in the first group agrees with numerous earlier reports. The fact that the reduced intake occurred in a group

TABLE 4-11
The effect of pelleting and feed restriction on chick performance with corn and triticale based diets

Grain source	Treatment type	Body weight* (g)	Feed intake* (g)	Feed conversion* (g/g)
Corn	*Ad lib* mash	640^{b}	918^{a}	1.45^{a}
Triticale	*Ad lib* mash	654^{b}	831^{c}	1.31^{b}
Corn	Restricted mash**	585^{c}	748^{d}	1.30^{bc}
Triticale	Restricted mash**	589^{c}	739^{d}	1.27^{c}
Corn	*Ad lib* pelleted	686^{a}	388^{ab}	1.30^{bc}
Triticale	*Ad lib* pelleted	661^{b}	858^{bc}	1.33^{b}

* Means with different superscripts within a column are significantly different ($P \leq .05$) according to Duncan's Multiple Range Test.

** Restricted to 95% of consumption level of *ad libitum* fed corn control.

which grew as well as the group fed the corn based diet indicates that the triticale diet supported better efficiency than the corn based diet. This is a positive indication of nutritional quality for the triticale based diet. Had the diet contained dominant antinutritional factors or contaminants like ergot, these would be expected to reduce the efficiency of utilization and would show up as reduced feed conversion and/or growth.

Restricting the intake of the second group of birds to 95% of _ad libitum_ levels equalized the intake for the two basal diets. When triticale intake was equivalent to corn, no significant difference in growth rate was observed. Feed efficiency for the restricted triticale based diets was not significantly better than for the corn based diets. Restricting the intake of corn fed birds to match the intake of triticale fed birds would be expected to eliminate differences in growth resulting from intake differences attributable to the increased bulk of the triticale. With the trend towards better feed efficiency observed in birds fed triticale based diets, this equalization of intake would seem to favor the triticale fed birds. The data from this trial indicate that triticale fed birds grew as rapidly as corn fed birds when they consumed the same amount of nutrients but it does not support the conclusion that they can surpass the rate of growth obtained by feeding corn based diets. Therefore, it cannot be concluded that bulk was the limiting factor in these triticale based diets. In this trial, pelleting enhanced growth and efficiency in the birds fed the corn based diet but did not appreciably affect the performance of the birds fed the triticale

based diet. Pelleting would be expected to increase density and therefore reduce the time required to ingest adequate nutrients for optimum growth (Jensen, 1962). This would diminish the effect of increased bulk from the triticale, and enhanced performance in birds fed pelleted triticale based diets would be expected if bulk were the factor limiting intake. No improvement in growth or efficiency from the pelleting of triticale was observed in this study. The data from this trial indicate no enhancement to growth parameters of birds fed triticale based diets by treatments which minimize the effect of bulk in the diet. These treatments would have been expected to enhance performance if bulk were the limiting factor in the diets. Since this enhancement was not supported by the data, it can be concluded that dietary bulk is not responsible for the reduced feed intake frequently observed in birds fed triticale based diets.

Experiment #3

No growth depression was observed in birds fed the triticale based diets with either the TVMP or CVMP added (Table 4-12). This provides further evidence of the ability of the basal triticale based formulation (Table 4-4) determined in this series of experiments to promote optimal growth.

The use of the TVMP did not enhance growth or feed efficiency of the birds beyond the levels obtained from feeding diets containing the CVMP (Table 4-12). In this study, the CVMP was shown not to be limiting for the corn or triticale based diet. An indication of adequacy for the CVMP signifies that not only choline and vitamin E levels are adequate, but the vitamin-mineral premix formulations

TABLE 4-12
Comparison of broiler performance and conversion with chicken and turkey vitamin-mineral premixes

Diet*	Body weight** (g)	Feed conversion** (g/g body wt)
1. Corn + CVMP	611[a]	1.34[a]
2. Corn + TVMP	613[a]	1.35[a]
3. Triticale + CVMP	600[a]	1.34[a]
4. Triticale + TVMP	608[a]	1.33[a]

* Diets designated with "+ CVMP" contain chicken vitamin-mineral premix while those with "+ TVMP" contain turkey vitamin-mineral premix.

** Means with different superscripts within a column are significantly different ($P \leq .05$) according to Duncan's Multiple Range Test.

(Table 4-2) shows that the TVMP also contains higher concentrations of niacin, biotin, and zinc than does the CVMP. A growth response to the use of TVMP would probably have been observed if any of these micronutrients was limiting in the CVMP. The data (Table 4-12) provide no indication of this.

The acceptable growth that was observed also provided confirmation of the adequacy of the diet to meet the requirements of certain more complex metabolic interactions. Choline is needed for its role in the formation of acetylcholine, in the metabolism of fats, and for its contribution of labile methyl groups to the diet. It is a part of phospholipids and behaves as a "lipotropic factor" by hastening the removal, or by decresing the deposition of liver fat, thus preventing development of fatty livers (McDowell, 1985). Triticale diets in Experiment #3 contained 22% more total lipids than did the corn diets. This would be expected to increase the metabolic need for choline and to produce higher than normal fat deposits in the livers of birds receiving inadequate levels of choline. A number of birds from each treatment were necropsied at the termination of Experiment #3 and no recognizable differences in liver lipid deposits could be detected.

Choline has also been shown to be related to the methionine and sulfate adequacy of the diet (Miles et al., 1983; Ruiz et al., 1983; McDowell, 1985). Choline can spare methionine in the diet by supplying labile methyl groups which methionine might otherwise have supplied, or through the formation of betaine which can methylate homocysteine which is thereby converted to methionine (Miles et al.,

1983; Ruiz _et al._, 1983; McDowell, 1985). However, it should be noted that the conversion of betaine to methionine may be highly inefficient. Miles _et al._ (1983) cited a study by Harter and Baker in which they used L-homocysteine in a synthetic L-amino acid diet to test the ability of homocysteine to spare either methionine _per se_ or cysteine _per se_ and found that the conversion of homocysteine to methionine was inefficient.

It can be concluded that the choline supplied by the diet and CVMP combination was adequate to supplement the chick's natural synthesis to meet _per se_ needs and additionally spare methyl groups to ameliorate deficiencies in methionine if any existed in the diet. The NRC (1977) suggests that very little evidence supports the need for choline supplementation in practical pullet growing rations or laying rations and attributes this to a high rate of natural synthesis by the bird. Choline is also present in adequate amounts in the cereals and natural fats which predominate in diets of Experiment #3.

Vitamin E is a lipid soluble vitamin and is part of a group of vitamins called tocopherols which vary widely from 1-100% of the activity of the standard alpha-tocopherol (McDonald _et al._, 1981). Chicks deficient in vitamin E may show signs of degeneration of the germinal epithelium, encephalomalecia, exudative diathesis, anemia, hemolysis, discoloration of adipose tissue, and liver necrosis (McDowell, 1985). The vitamin has been shown to inhibit lipid oxidation (Calvert _et al._, 1964; Bartov and Bornstein, 1976b; McDowell, 1985) and plays a role in preventing oxidative damage to

tissues. It is found widespread in nature where the richest sources include vegetable oils and cereal products containing the oils.

The triticale and corn diets formulated for Experiment #3 utilized corn oil as a supplemental lipid source and were not expected to be deficient in vitamin E. The original objective of the study was to investigate the source of a better than average growth response to a diet supplemented with TVMP. Depressed growth was not observed. No growth impediment or physical manifestation of vitamin E deficiency was observed with the live birds, and necropsies conducted after the experiment revealed no abnormalities of the liver or other tissues that would indicate the birds were vitamin deficient.

On the basis of the data collected in this experiment, higher than NRC recommended (NRC, 1977) levels of vitamins and micronutrients cannot be used as an explanation for differences in response to triticale compared to corn observed in previous research trials.

CHAPTER V
THE INFLUENCE OF DIETARY FAT AND GRAIN SOURCE ON THE GROWTH, CARCASS COMPOSITION AND FLAVOR, FAT PAD WEIGHTS AND FATTY ACID COMPOSITION, LIVER LIPID CONCENTRATIONS AND SHANK PIGMENTATION OF BROILERS

Introduction

It was demonstrated in the previous two chapters that chicks fed alternate grains could achieve acceptable growth during the first 21 days when NRC (1977) recommended levels of energy, protein, and vitamins were provided in a battery cage environment.

The first part of the following experiment was designed to evaluate the performance of birds fed corn, triticale, wheat, or milo based diets throughout the grow-out period (49 days) under conditions more closely simulating the commercial growing environment. The diets were supplemented with animal fat or corn oil to determine the relative feeding value of the alternate grain and fat source combinations.

The total value of an alternate cereal grain cannot be determined solely on the basis of weight gain and feed conversion. Flavor, body lean, fat composition, liver fat deposits, and the stability of the carcass fat against oxidation must all be considered. The grain source and its corresponding lipid supplement have been shown to influence carcass composition (Jensen, 1973; Rinehart et al., 1975; Kim et al., 1976; Hulan et al., 1984). Flavor can also be altered

(Petersen, 1969) as can the fatty acid composition (Marion and Woodroof, 1963, 1966; Salmon and O'Neil, 1973; Bartov et al., 1974b; Webb et al., 1974). This altered fatty acid composition can ultimately affect the physical properties and storage stability of the carcass fat (Marion and Woodroof, 1963, 1966; Edwards et al., 1973; Salmon and O'Neil, 1973; Bartov and Bornstein, 1976b). Liver lipid levels can also be affected by dietary grain (Jensen et al., 1974).

The second part of the following experiment was designed to evaluate the effect of feeding practical alternate grain based diets on the carcass composition and flavor, fat pad weights and fatty acid composition, liver lipid concentration, and shank pigmentation of broilers.

Materials and Methods

Broiler Growth

A total of 576 day-old Cobb feather sexable chicks were randomized and placed in 5' x 5' floor pens with new wood shavings litter. Four males and four females were placed in each pen. Eight pens were selected for each of the nine treatments in a manner designed to ensure equal representation of treatments on inside and outside rows on both sides of the house. The house is oriented East and West on the longitudinal axis so that half of the birds, one inside and one outside row, received Northern exposure while the other half received a Southern exposure. This block design was to minimize differences in pigmentation and feed intake which might result from the differences in lighting and which might otherwise contribute to

the variability of the data. Thermostatically controlled heat lamps in each pen ensured the maintenance of a comfortable temperature zone for the chicks. A constant supply of fresh tap water was provided by a Little Giant Chick Fountain in each pen. These fountains were located at the ground level on day one and were adjusted as needed after the first week to be shoulder height for the chicks. The fountains were cleaned daily to prevent the buildup of shavings or other contaminants. All chicks were identified by wing banding on day one to facilitate identification of the carcasses during the processing phase of the experiment.

Nine starter diets (Table 5-1) were mixed and weighed individually into the containers placed in the appropriate pens. From these containers feed was placed on cardboard egg flats located on the floor for the first three days of the trial to help the chicks to adjust to the gravity flow tube feeders which were partially filled and placed at ground level. These feeders were shaken daily to ensure a constant feed supply for chicks. During the starter period Amprol® coccidiostat was provided in the water.

The birds in each pen were individually weighed and total feed consumption for each pen was determined on day 21. At this time the starter diets were removed from the pens and replaced by the finisher diet (Table 5-2) which was fed through day 42, the balance weighed, and removed from the pens. Withdrawal diets, identical to the finisher diets but without the coccidiostat, were then weighed into the appropriate pen containers and fed for the final week. On day 49

TABLE 5-1
Composition and calculated nutrient content of the experimental starter diets

Ingredient*	Diet No.								
	1	2	3	4	5	6	7	8	9
Corn	52.99	52.34	52.34	-	-	-	-	-	-
Triticale	-	-	-	54.93	53.68	-	-	-	-
Wheat	-	-	-	-	-	55.26	54.22	-	-
Milo	-	-	-	-	-	-	-	55.64	54.83
Soy (48.5%)	37.89	37.93	37.93	33.27	33.58	33.86	34.13	35.17	35.33
Limestone	1.11	1.11	1.11	1.08	1.08	1.07	1.04	1.09	1.09
Dical Phos.***	1.72	1.72	1.72	1.68	1.68	1.73	1.73	1.67	1.67
Salt	.40	.40	.40	.40	.40	.40	.40	.40	.40
Vit-Min.**	.50	.50	.50	.50	.50	.50	.50	.50	.50
DL-Meth.	.19	.20	.20	.26	.25	.24	.24	.23	.23
Corn Oil	5.20	-	-	7.91	-	6.94	-	5.30	-
Animal Fat	-	5.80	5.80	-	8.83	-	7.74	-	5.95
Lysine	-	-	-	-	-	-	-	-	-
Nutrients*									
Protein	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
Lipid	7.59	8.17	8.17	9.17	11.38	8.03	8.81	7.10	7.55
Linoleic	4.23	1.88	1.88	5.57	1.47	4.78	1.65	3.82	1.45
Calcium	.90	.90	.90	.90	.90	.90	.90	.90	.90
Total Phos.	.70	.70	.70	.70	.70	.69	.69	.70	.69
Arginine	1.66	1.66	1.66	1.57	1.58	1.58	1.59	1.52	1.52
Cys. + Meth.	.93	.93	.93	.93	.93	.93	.93	.93	.93
Threonine	.93	.92	.92	.84	.84	.80	.80	.87	.87
Lysine	1.32	1.34	1.34	1.29	1.30	1.27	1.27	1.25	1.25
Tryptophan	.30	.30	.30	.31	.31	.30	.30	.28	.28
MEn (Kcal/Kg)	3200	3200	3200	3200	3200	3200	3200	3200	3200

* Ingredient and nutrient values expressed as g/100 g of diet unless labelled otherwise.

** Standard University of Florida chick micronutrient premix (Table 4-2).

*** Contains 22% Ca and 18.5% P.

TABLE 5-2
Composition and calculated nutrient content of the experimental finisher diets

Ingredient*	Diet No.								
	1	2	3	4	5	6	7	8	9
Corn	64.79	64.43	65.50	-	-	-	-	-	-
Triticale	-	-	-	62.79	53.68	-	-	-	-
Wheat	-	-	-	-	-	63.52	62.70	-	-
Milo	-	-	-	-	-	-	-	66.08	65.64
Corn Glu (60)	3.00	3.00	-	3.00	3.00	3.00	3.00	3.00	3.00
Soy (48.5%)	25.59	25.62	26.89	23.73	23.30	24.15	24.34	23.67	23.78
Limestone	1.02	1.02	1.05	1.09	1.05	1.08	1.07	1.11	1.13
Dical Phos.***	1.83	1.83	1.89	1.79	1.82	1.84	1.84	1.79	1.74
Salt	.40	.40	.40	.40	.40	.40	.40	.40	.40
Vit-Min.**	.50	.50	.50	.50	.50	.50	.50	.50	.50
DL-Meth.	.03	.03	.10	.07	.07	.04	.05	.07	.07
Corn Oil	2.73	-	-	6.53	-	5.37	-	3.22	-
Animal Fat	-	3.06	3.57	-	7.19	-	6.00	-	3.59
Lysine	.01	.01	-	-	-	-	-	.06	.05
Co-Ban®	.10	.10	.10	.10	.10	.10	.10	.10	.10
Nutrients*									
Protein	20.00	20.00	18.00	21.26	20.98	21.12	20.78	20.41	20.41
Lipid	5.53	5.85	6.33	7.82	8.47	6.55	7.17	5.26	5.62
Linoleic	2.98	1.75	1.84	4.23	1.28	3.91	1.50	2.63	1.24
Calcium	.90	.90	.90	.90	.90	.90	.90	.90	.90
Total Phos.	.70	.70	.70	.70	.70	.70	.70	.70	.70
Arginine	1.32	1.32	1.32	1.33	1.31	1.33	1.35	1.20	1.21
Cys. + Meth.	.72	.72	.72	.72	.72	.72	.72	.72	.93
Threonine	.80	.80	.78	.74	.74	.74	.74	.75	.75
Lysine	1.00	1.00	1.02	1.04	1.03	1.02	1.02	1.00	1.00
Tryptophan	.24	.24	.24	.27	.27	.25	.24	.22	.22
MEn (Kcal/Kg)	3200	3200	3200	3200	3200	3200	3200	3200	3200

* Ingredient and nutrient values expressed as g/100 g of diet unless labelled otherwise.

** Standard University of Florida chick micronutrient premix (Table 4-2).

*** Contains 22% Ca and 18.5% P.

the birds from each pen were individually weighed and the total pen feed consumption was determined.

Two males and two females from each pen were visually selected for uniformity of size (by sex) and fleshing and were leg banded. A processing group was formed by collecting one male and one female from each of the nine treatments within a growout block. The sexes were cooped separately within the processing group. These cooped birds were held without food and water for 12 hr, and transported to the University of Florida processing facility for processing and further evaluation of carcass parameters.

A total of two additional males and two females selected for uniformity (within sex) were removed from different reps of treatments 2, 5, 7, and 9 (corn, triticale, wheat, and milo supplemented with animal fat, respectively) and cooped in processing groups containing one male and one female from each treatment. These birds were also held without food and water for 12 hr before being transported to the processing facility. These birds were previously identified by wing bands. After processing, this second batch of birds would be cooked and served as part of the sensory evaluation of carcasses from different cereal grain sources.

Processing

Each processing group of nine birds from a single coop and sex were individually weighed and hung on shackles, stunned, and killed by exsanguination. After bleeding for two minutes, the birds were removed from the shackles. From each bird, the banded leg was severed at the hock joint and the shank placed in an ice bath for later

pigmentation analysis. The birds were then subscalded using an Ashley model #SS-36 vat-type scalder (60 C, 45 seconds) and feathers were removed by an Ashley model #SP-38 commercial rotary drum picker (25 seconds). During evisceration, the liver and fat pads were removed, cleaned of extraneous tissues, weighed individually, and placed in separate (labeled) plastic sample bags. Following evisceration the carcasses were rinsed, allowed to drain for two minutes, and weighed (without giblets) to determine the prechill dressed carcass shell weight. The weight of the fat pads were added to this weight to determine the "whole" prechill dressed carcass weight. After weighing, the carcasses were placed in individual Cryovac® bags (from Cryovac Div. of Grace & Co., Duncan, SC). These in turn were placed in a larger plastic bag which held the nine carcasses from a single half (one sex) of a processing group. After this process was completed for both sexes, the carcass, fat pad and liver samples were placed in the freezer (without prior chilling) where they were maintained at -23 C until subsequent analysis (approximately 5 months).

Birds from the sensory panel group were processed in a similar manner as described previously, except that they were chilled after being processed. Carcasses were immersed in the 1 C chill tank (ice slush) where they were held for 14 hr under mechanical agitation, packed in individual Cyrovac bags, and then held for 24 hr at 2 C before preparation for sensory panel evaluation.

Sensory Evaluation of Flavor

All carcasses were placed breast side up in aluminum foil lined and covered pans equipped with roasting racks and cooked in a conventional electric oven (177 C) to an internal temperature of 85 C. Oven thermometers were placed in the thickest portion of the breast to indicate internal temperature during cooking. Cooked carcasses were cooled and held at 2 C for 24 hr prior to sample preparation. The pectoralis superficialis muscles from the cooked breasts were then removed and diced into bite size pieces (about 2 x 2 x 1 cm). Dark meat samples were removed from the drumstick and thigh and similarly diced into bite size pieces for use in sensory analysis. A Triangle Difference Test was chosen to compare the carcasses because it is useful for determining whether an ingredient substitution results in a detectable difference in the product (Larmond, 1977). Sensory panelists were given three coded samples per plate and told that two samples were the same and that one was different. The panelist was asked to identify the odd sample. Three plates were evaluated by each panelist: the first contained a corn versus triticale comparison, the second compared corn to wheat and the third compared corn to milo. Four panels were held with seven panelists each. The first panel evaluated breast samples from males, the second dark meat from males, the third breast meat from females, and the fourth dark meat from females. A comments section was included on each questionnaire (Figure 5-1) and the comments were evaluated for trends after the number of correct answers were

QUESTIONNAIRE FOR
TRIANGLE TEST

STATION 7
PLATE A

NAME ______________________ DATE ______________

PRODUCT: Chicken Meat Sample

Two of these three samples are identical, the third is different.

1. Taste the samples in the order indicated and identify the odd sample.

Code	Check odd sample
210	______
257	______
430	______

2. Indicate the degree of difference between the duplicate samples and the odd sample. (Make a check by your answer.)

Slight	______
Moderate	______
Much	______
Extreme	______

3. Acceptability

Odd samples more acceptable	______
Duplicates more acceptable	______

4. Comments

FIGURE 5-1
Sample questionnaire for the Triangle Test

tabulated; less than five correct answers were not considered significant (Larmond, 1977).

Shank Pigmentation

Banded shanks were removed from the ice bath 24 hr after processing and a section of skin approximately 4 x 4 cm was removed and placed flesh side down on a 5 x 5 cm white cardboard card. The skin side of each sample was then evaluated for pigment level utilizing a McBeth MC-1010S reflectance colorimeter. The readings obtained from the colorimeter were converted by a computer program, developed by Fry and Damron (1971), into dominant wavelength (DW), excitation purity (EP), and luminosity (LUM) values. These data were subjected to analysis of variance and Duncan's Multiple Range Test (Steel and Torrie, 1960) using computer programs available in the Statistical Analysis System (SAS, 1982).

Carcass Proximate Analysis

Frozen carcasses were removed from the freezer and thawed at 2 C for 48 hr before being grouped by pen and sex. Both carcasses from the same sex and pen were cut into individual parts with a circular cut-up saw and placed together in a Cryovac bag which was tagged and labeled by pen, sex, group, and treatment. Each group contained 18 bags (36 carcasses) and was designed to minimize sampling bias by including two birds from each sex for each of the nine treatments and thus control for variation between analytical sessions. Four groups were formed from the 144 carcasses analyzed.

The cut up carcasses were held at 2 C for 24 hr prior to grinding and then equilibrated to approximately 22 C (4 hr) to minimize

moisture condensation. The pair of cut up birds from each individual bag was then ground with a Toledo Chopper, Model #5223, by making two passes through a coarse grind (1.0 cm) hole size and three passes through a fine grind (0.3 cm) hole size to insure a homogenous sample. Any fluid found in the original sample bag was mixed with the homogenate prior to the fine grinding passes. From the ground product thus formed, two 50 g samples were removed and placed in separate sample bags labeled by pen, sex, treatment and group. The balance of the homogenate was replaced in the original Cryovac bag, refrozen (-23 C) and held for possible future analysis. The grinder was disassembled, cleaned with hot water, allowed to drain for five minutes, and towelled dry between samples. After all birds from a group were ground, the corresponding sample bags were placed into a Cryovac bag, labelled by group, and held (24-120 hr) at 2 C until subsequent chemical analysis.

Moisture, ether extract and ash determinations were made in duplicate by procedures described by AOAC (1984). Moisture was determined by weight loss through oven drying (100 C, 16 hr) 10 g samples. The dried samples from above were then extracted overnight in petroleum ether, redried, and reweighed to determine the weight loss. Ash content was determined by weighing the ash residue left in a crucible after heating at 550 C for 10 hr in a muffle furnace. Following a procedure outlined by Peterson (1984), moisture, ether extract and ash values were subtracted from 100 to obtain an estimate of protein content.

These data were subjected to analysis of variance and Duncan's Multiple Range Test (Steel and Torrie, 1960) utilizing computer programs available through the Statistical Analysis Systems (SAS, 1982).

Liver Moisture and Lipid Analysis

"Liver yield" was calculated as the weight of the liver (determined at the time of processing) x 100 divided by the whole prechill carcass weight (described in a previous section). Samples were removed from the freezer and held at 2 C for 48 hr in preparation for analysis, then arranged into eight analytical groups (288 livers) by the same procedure described for the whole carcass analysis. Each pair of livers was individually blended in a 100 ml stainless steel cup at medium high speed (approximately 14,000 rpm) using a Virtis 23 homogenizer for 30 seconds prior to reintroduction into one of the original sample bags labelled by pen, sex, group and treatment. The individual sample bags were arranged into groups, placed in larger bags, and held (24 hr, 2 C) until analysis. Duplicate 10 g samples were analyzed for moisture and ether extract by the same procedures described above for the whole carcass analysis. The resulting data were statistically analyzed by the methods described in the previous section.

Fat Pad Yield and Lipid Concentration

The fat pad yield was calculated as the fat pad weight (g, determined at time of processing) x 100 divided by the whole prechill dressed carcass weight (g). Fat pads from all birds from treatments 2, 5, 7 and 9 were separated from the other fat pad samples, removed

from the freezer, and held (48 hr) at 2 C until prepared for analysis. Eight analytical reps were formed. Each contained one pair of fat pads/sex/pen from treatments 2, 5, 7, and 9. Both fat pads from each pair were trimmed of extraneous tissues, chopped into approximately 1 g pieces and combined. A 10 g composite of portions from both fat pads (same sex) was then weighed out for extraction of lipids and analysis of fatty acids. Lipids were extracted by a chloroform, methanol and water based procedure modified by West (1985) from procedures published by Bligh and Dyer (1959) and De Lumen et al. (1974). A 10 g (weight recorded) composite fat pad sample and 90 ml of 20:1 chloroform:methanol were blended at approximately 1200 rpm for 7 min in a Waring blender under a safety hood. The homogenate was then filtered through a Buchner funnel (Whatman No. 2 filter paper and suction for 3 min) and placed in a 250 ml separatory funnel. To this was added 16 ml of distilled-deionized water (22 C). The funnel was stoppered and mixed for 2 min by shaking and inversion, placed in an upright storage rack, and held (20 min, 22 C). The chloroform and lipid portion (heavy phase) was then separated into a weighed rotary evaporative flask (250 ml) and rotoevaporated (40 rpm, 37 C, 20 min) under vacuum until the odor of chloroform was barely detectable. Nitrogen gas (5 psi) was then blown into the sample (enough to see a rippled surface) for 5 min to remove most of the remaining chloroform. The flask and sample were then reweighed to determine the weight of lipid sample remaining. This weight x 100 divided by the weight of the original sample (about 10 g) was considered to represent the percent lipid contained in the fat pad. Approximately .1 g of the

lipid sample was then weighed into a 10 ml volumetric flask and brought to 10 ml with reagent grade chloroform. These samples were placed in consecutively numbered tubes, capped (teflon lined) and held (1 wk) at -23 C, esterified and chromatographed as described in the next section.

Fatty Acid Chromatography

Gas chromatographic analysis of the fatty acids were measured by a procedure modified by West (1985). One milliliter aliquots of the chloroform-lipid samples were placed in labelled 1 ml serum bottles and capped (with septum cap). To this .2 ml Meth Prep II® (m-trifluoro-methyl-phenyl-trimethyl-ammonium hydroxide methylating agent from Alltech Applied Sciences, State College, PA) was added. After decanting three times, the samples were allowed to stand for 30 min before the bottles were loaded into the 35 positions of a Hewlett Packard (HP) 7671A Auto Sampler coupled with a HP 5840 Gas Chromatograph equipped with a hydrogen flame detector and a HP 5840A GC (data control unit and recorder) Terminal. Sample bottles containing Supelco AOCS oil (1 mg/ml) reference mixture #RM-6, 4-7025 in chloroform (from Supelco Inc., Bellefonte, PA) were placed in positions #1 and #35 of the sample belt to provide a cross check against instrumental variability throughout the sampling run. Two runs were necessary to accommodate the 64 sample bottles and 3 standard bottles. Injections (1 ul) were made by the auto sampler into a 2 m x 4 mm I.D. glass column packed with 10% Silar 10C on 100/120 Gas Chrom QII (from Applied Science, State College, PA). The injection port temperature was maintained at 250 C, the detector

temperature at 300 C, and the column oven temperature was programmed to maintain 150 C for 3 min and then increase at the rate of 2 C/min to final temperature of 200 C which was maintained for 60 min. A carrier gas flow (nitrogen) was instrumentally metered and maintained at 60.6 cc/sec. Nitrogen, hydrogen and air line (gas) pressures were maintained at 40, 40 and 20 psi, respectively. Chart speed was .20 cm/min and attenuation was set at 6 for the first 4 reps and at 7 for the last 4 reps. Slope sensitivity was set to allow detection of a .15 change in slope and include all peaks with areas greater than approximately .28% of the total area of peaks from fatty esters eluting between 20 and 80 min after injection. The concentration of methyl ester of each fatty acid which eluted between 20 and 80 min was calculated as a percent of the total fatty esters eluting during that time period. The chloroform solvent and esterifying agent peaks were excluded from the calculation by auto rejection of peaks eluting before 20 min.

Peaks were identified by comparison of elution times with those observed from known standards, comparison of spectra with previously published spectra, and by comparison with standard curves generated by plotting the log of elution time versus carbon chain length for known saturated and mono-unsaturated fatty acids.

The data were subjected to analysis of variance and Duncan's Multiple Range Test (Steel and Torrie, 1960) using computer programs from Statistical Analysis Systems (SAS, 1982).

Results and Discussion

Broiler Growth

For the first 21 days birds fed triticale, wheat or milo supplemented with corn oil (CO) grew as well as those fed the corn basal with CO (Table 5-3). The wheat and milo based diets with CO supported better growth than the triticale based diet with CO ($P \leq .05$). The birds fed the triticale based diet were more efficient than those fed the corn control diet as was expected on the basis of the results of previous experiments in this series (Table 4-10). However, the triticale based diet did not support as good a feed efficiency in this experiment as it had in the previous ones. The birds fed the corn based diet with CO were also slightly less efficient than they had been in experiments described in Chapters III and IV of this manuscript. The cause of this reduced efficiency is unknown.

The performance of the birds fed AF supplemented diets was generally below that for the CO supplemented diets. This difference did not manifest itself as clearly in body weight, where $P > .05$ for comparisons of body weight between CO and AF supplementation for the same grain source, as it did in the feed efficiency results. A comparison of CO and AF for each grain source indicated that CO supported numerically better efficiency in every case. This was particularly true for triticale based diets where the AF decreased efficiency by 6.4% ($P \leq .05$). In Experiments #1 and #2 from Chapter III, it was reported that triticale based diets supported acceptable growth when 3200 Kcal ME/Kg were provided (Table 3-5) but that

TABLE 5-3
Effect of fat source on performance of chicks fed corn, triticale, wheat and milo diets

Diet*	21 days		49 days	
	Body weight** (g)	Feed conversion** (g/g)	Body weight** (g)	Feed conversion** (g/g)
Corn + CO	553^{ab}	1.45^{b}	1872^{abc}	1.86^{c}
Corn + AF	540^{bc}	1.47^{ab}	1809^{c}	1.97^{a}
Average	547	1.46	1841	1.92
Triticale + CO	530^{bc}	1.40^{c}	1922^{ab}	1.85^{c}
Triticale + AF	516^{c}	1.49^{a}	1849^{bc}	1.96^{ab}
Average	523	1.45	1886	1.91
Wheat + CO	588^{a}	1.37^{c}	1956^{a}	1.85^{c}
Wheat + AF	577^{a}	1.39^{c}	1900^{ab}	1.85^{c}
Average	583	1.38	1928	1.85^{c}
Milo + CO	579^{a}	1.38^{c}	1913^{ab}	1.88^{c}
Milo + AF	582^{a}	1.39^{c}	1878^{abc}	1.91^{bc}
Average	581	1.39	1898	1.90
Average CO	563	1.40	1919	1.87
Average AF	554	1.44	1860	1.92

* CO = Corn oil supplementation, AF = Animal fat supplementation.

** Means with different superscripts within a column are significantly different ($P \leq .05$) according to Duncan's Multiple Range Test.

Marion et al. (1984) had observed growth depression when only 3124 Kcal ME/Kg were furnished by the diet. This would seem to indicate that the performance of birds fed triticale based diets may be closely linked to the dietary energy levels. In the current experiment the data support the possibility that energy levels of the diets supplemented with animal fat fell below that needed for optimum growth. Since the supplemental fat source was the primary difference between the diets, it can be concluded that the animal fat did not contribute the ME that it was calculated to contain. It is difficult to assign an accurate ME value to animal-poultry fat (Whitehead, 1986) because many variables may influence the actual energy levels (NRC, 1984). Moisture levels, free fatty acids, unsaponifiables, total fatty acids, impurities and fatty acid composition are all known to affect the true ME values of a fat source (NRC, 1984). Absorption of the fat source can also be affected by the nature of the dietary fat. Renner and Hill (1961), Young (1961), and Lewis and Payne (1966) reported a synergistic relationship was created by the addition of a source of unsaturated fats into more highly saturated fats and that the addition of the unsaturated fat significantly enhanced the normally poor absorption of palmitic and stearic acids. Ward and Marquardt (1983) demonstrated that the grain source also influenced the nature of the fat in the diet and that this could exert an influence on the fat absorption of the birds. Since triticale has less oil than corn and this oil is more saturated than corn oil, it is possible that its combination with the more saturated animal-poultry fat did not produce a mixture containing an adequate level of

unsaturated fat for the synergism of mixture to occur (thus producing lowered energy value). The use of AF numerically reduced efficiency for all of the grains in this study which indicates that it does not supply the level of energy for any of the diets which it was formulated to provide.

The results of the first phase of this experiment indicate that variation may occur in the feeding value of grains and fat sources which may not be predictable on the basis of published estimated values. This finding supports the need for uniformity in feedstuffs which can only be guaranteed through a stringent quality control and testing program for all incoming ingredients.

The birds appeared to compensate during weeks 4-7 for their early (21 day) mediocre performance (Table 5-3). Particularly noticeable was the recovery of the birds fed the triticale based diet supplemented with corn oil. This group responded well to the finisher diet and gained 1 g more body weight per day (49.87 g/day) than any of the other groups of birds during this period. While differences were not significant at the $P \leq .05$ level, it is clear that the triticale, wheat, and milo based diets supplemented with corn oil supported better overall growth (49 day) than the corn based diet. No differences in efficiency were observed between grain sources for the birds fed corn oil supplemented diets when the total performance for the 49 day period was analyzed. The 1.87 g feed/g body weight average for these birds is commercially acceptable.

Animal fat supplemented diets supported 5 points poorer feed conversion (on the average) than the corn oil supplemented diets

during the full 49 day study. Wheat based diets provided the best conversion and corn based diets the poorest, with triticale and milo based diets intermediate in quality ($P \leq .05$). Apparently, the limiting aspects of the triticale based starter diet containing animal fat were corrected in the finisher diet so that compensatory growth occurred.

The data from this experiment show a difference in feeding value between animal-poultry oil and corn oil when the two are included in alternate grain based formulation at 3750 and 4009 Kcal ME/Kg, respectively. The reduction in performance was not consistent across all grains, rather it reduced the growth and efficiency for triticale and corn more than for wheat and milo. This unexpected variability indicated a need for better control of the quality of feeding ingredients in commercial applications and a need for uniformity of ingredient supplies used for experimental work. The use of corn oil as a more uniform supply of supplemental fat can be recommended for many studies where the elimination of unnecessary variability is a necessity. This research could then be verified with animal fat diets to more closely simulate commercial growing conditions. Failure to evaluate both fat sources with a new grain source could ultimately lead to inability to determine certain relationships (due to high inherent variability) or even to false conclusions.

Sensory Evaluation

Petersen (1969) suggested that the tannin in sorghum diets fed to broilers may have been responsible for a detectable difference in taste observed between corn and sorghum fed birds, corn, triticale, wheat, and sorghum (milo). The data from this trial (Table 5-4)

TABLE 5-4
Sensory comparison of the baked carcasses from broilers fed corn based diets and those fed triticale, wheat or milo based diets

Panel* no.	Triticale		Wheat		Milo	
	Right	Wrong	Right	Wrong	Right	Wrong
1	1	6	4	3	7**	0
2	4	3	3	4	3	4
3	4	3	4	3	2	5
4	3	4	4	3	2	5

* Panel 1 = light meat (males), Panel 2 = dark meat (males), Panel 3 = light meat (females), and Panel 4 = dark meat (females)

** P<.01; others NS.

indicate that no detectable differences in flavor could be attributed to grain source. The data indicate that panelists were able to detect the odd sample when light meat from males fed milo based diets was compared to light meat from males fed corn based diets. It was observed that the pectoralis superficialis samples from the birds fed milo based diets were unexplainably tougher than the other samples. Interviews with panelists and comments made on the questionnaires indicate that panelists were keying on the difference in texture rather than taste to pick the odd sample in that comparison. The other three panels were clearly not able to distnguish between the corn and the milo fed birds.

These data are important to the poultry industry because they support the conclusion that broilers can be reared on the alternate grains tested in this study without detriment to the flavor of the carcass.

Shank Pigmentation

Poultry nutritionists have long been aware of the differences in xanthophyll content of various grains. For this study a corn based diet supplemented with 3% corn gluten meal (60% protein) was used as a basal diet designed to be representative of a commercial diet. A corn based diet without the corn gluten meal was included in the treatments to provide a comparison of the contribution to pigment attributable to corn alone. From Table 5-5 it is evident that considerable differences exist in shank pigmentation due to differences in the xanthophyll content of the grains compared to corn. The dominant wavelength (DWL) reading gives a qualitative indication of the hue of the shank. Higher numbers indicate a more yellow pigment provided by the

TABLE 5-5
Influence of dietary grain on shank pigmentation

Diet	Fat*	Pigmentation values**		
		DWL***	EP***	LUM***
Corn/Soy	CO	578.70[a]	43.37[a]	54.14[b]
Corn/Soy	AF	578.52[a]	44.46[a]	54.59[b]
Corn/Soy****	AF	578.16[b]	39.49[b]	56.33[a]
Triticale/Soy	CO	577.66[d]	30.88[e]	57.05[a]
Triticale/Soy	AF	577.79[cd]	31.50[e]	57.06[a]
Wheat/Soy	CO	577.95[bc]	33.65[d]	56.14[a]
Wheat/Soy	AF	577.79[cd]	35.55[c]	56.45[a]
Milo/Soy	CO	577.92[bcd]	33.59[d]	56.33[a]
Milo/Soy	AF	577.90[cd]	35.19[cd]	56.73[a]

* CO = Corn oil supplementation, AF = animal fat supplementation.

** Means with different superscripts within a column are significantly different ($P \leq .05$) according to Duncan's Multiple Range Test.

*** DWL = dominant wavelength, EP = excitation purity, LUM = luminosity.

**** Contains no corn gluten meal.

xanthophyll. The excitation purity (EP) is also important because it indicates the intensity of the color. This is a quantitative measurement and indicates the actual amount of pigment present. The luminosity (LUM) is not generally considered to be as important as DWL or EP because it shares an inverse relationship with the EP. It is also a quantitative measurement and indicates the amount of lightness of the sample. Samples with a high EP are less deeply pigmented than those with a low EP.

No pigmentation differences could be attributed to differences in fat source for this trial. The corn based diets with corn gluten meal produced the most highly pigmented shanks with the highest EP and DWL as was expected. The corn based diet without the corn gluten ranked second in pigmenting ability, indicating the favorable pigmenting ability of the corn grain. Next, the wheat and milo based diets were equivalent in pigmenting ability, and the triticale based diets produced the lowest DWL and LUM values. These data may not be important to the broiler producer where no "branding" or advertising has produced a definite consumer preference for pigmented skin on broiler carcasses. Conversely, the data are important in areas where consumers prefer the more highly pigmented skin. In this event, it would be necessary to augment the xanthophyll levels in the wheat, milo and triticale based diets. This would increase the cost of feeding these grains and would have to be a part of the least cost matrix used to decide the economic feasibility of bringing these grains into the formulation.

Carcass Dressing Yield and Proximate Composition

Table 5-6 gives the carcass yield values observed from the feeding of different grain and fat source combinations. The dress weight figures reflect the differences in live weights observed. When the yield is calculated as the dress weight x 100 divided by live weight, it becomes evident that the grain source and fat combination did not affect the carcass dress yield.

No differences in ash content of carcasses from birds fed the various grain and fat source combinations could be detected (Table 5-7). Birds fed the corn oil supplemented diets generally had higher carcass protein concentrations than did the birds fed animal fat supplemented diets, as was evidenced by the fairly large differences between birds fed the two corn based diets, the triticale based diets and the milo based diets. A numerical difference also existed in comparison of chicks fed the two wheat diets but the difference was much smaller than for the other grain sources. Birds fed corn oil supplemented diets generally grew more efficiently than the birds fed animal fat supplemented diets (Table 5-4). No significant grain related differences were observed between the protein concentrations of the carcasses of birds fed the corn oil supplemented diets but the birds fed corn and triticale based diets did seem to retain slightly more nitrogen than the birds fed wheat and milo based diets. The carcasses of birds fed animal fat supplemented triticale and milo based diets contained lower protein levels ($P \leq .05$) than the carcasses from birds fed the other grain source. An inverse relationship is suggested between the lipid and moisture levels. Birds fed the corn

TABLE 5-6
The effect of alternate grain based diets on carcass yield

Dietary grain	Fat* source	Live weight	Dress weight	Carcass yield**
Corn/Soy	CO	1329^{b}	1176^{c}	64.29^{a}
Corn/Soy	AF	1807^{b}	1197^{bc}	66.11^{a}
Corn/Soy***	AF	1821^{b}	1217^{bc}	66.75^{a}
Triticale/Soy	CO	1868^{b}	1243^{abc}	66.90^{a}
Triticale/Soy	AF	1838^{b}	1219^{bc}	66.43^{a}
Wheat/Soy	CO	1964^{a}	1303^{a}	66.47^{a}
Wheat/Soy	AF	1888^{ab}	1268^{ab}	66.85^{a}
Milo/Soy	CO	1807^{b}	1249^{abc}	66.71^{a}
Milo/Soy	AF	1850^{b}	1240^{abc}	66.96^{a}

* CO = Corn oil supplementation, AF = Animal fat supplementation.

** Means with different superscripts within a column are significantly different ($P \leq .05$) according to Duncan's Multiple Range Test.

*** Contains no corn gluten meal.

TABLE 5-7
Carcass composition as effected by grain fed

Diet	Fat*	%Moisture**	%Lipid**	%Ash**	%Protein**
Corn/Soy	CO	63.46[abc]	15.88[ab]	2.95[a]	18.13[a]
Corn/Soy	AF	63.92[abc]	16.28[ab]	2.49[a]	17.30[bc]
Corn/Soy***	AF	64.02[ab]	15.73[ab]	2.57[a]	17.31[bc]
Triticale/Soy	CO	64.30[a]	15.15[b]	2.53[a]	18.02[a]
Triticale/Soy	AF	63.65[ab]	16.87[ab]	2.45[a]	17.03[c]
Wheat/Soy	CO	63.16[abc]	16.23[ab]	2.65[a]	17.89[ab]
Wheat/Soy	AF	63.70[abc]	15.91[ab]	2.57[a]	17.76[ab]
Milo/Soy	CO	62.66[c]	17.24[a]	2.70[a]	17.52[abc]
Milo/Soy	AF	62.84[bc]	17.57[a]	2.54[a]	17.05[c]

* CO = Corn oil supplementation, AF = animal fat supplementation.

** Means with different superscripts within a column are significantly different ($P \leq .05$) according to Duncan's Multiple Range Test.

*** Contains no corn gluten meal.

(AF) based diet and the triticale (CO) based diet had the most tissue moisture and least lipid levels while those fed the two milo diets had the lowest moisture levels and the highest lipid levels. Jensen (1973) and Kim et al. (1976) also reported a higher level of fat deposited from the feeding of milo based diets than from other grains. Since the two milo diets had the lowest total lipid content (Table 5-2), these data would tend to refute the possibility that the highest carcass fat levels result from the diets with the highest supplemental fat levels. All the diets were formulated to maintain the same calorie to amino acid ratio to minimize the variability due to this important factor as discussed earlier. In general, reducing this ratio is thought to lower fat accumulation in the carcass.

It is difficult to establish a pattern from the results of this part of the experiment. Feeding milo resulted higher carcass lipid concentrations than feeding the other grain sources. Also feeding the more efficient CO supplemented diets resulted in higher levels of carcass protein than did the use of AF supplemented diets. These CO supplemented diets also supported better feed efficiency than the AF supplemented diets. It has been suggested that reduced efficiency can result in the intake of more nutrients to meet dietary needs and thus produce a surplus of energy for fat deposition (Whitehead, 1986). This would seem to suggest that the AF supplemented diets would produce fatter carcasses than the CO supplemented diets. The mean lipid percent of the chicks was 16.47% for the AF supplemented diets and of 16.12% for the CO supplemented diets. This difference is not statistically significant. Also, it must be considered that the

reduced efficiency observed probably resulted from reduced energy levels of the AF supplemented diets; therefore, the increased intake would have been necessary to bring the energy up to needed levels and would not have produced energy excess. The AF provided less ME than the calculated value used in designing the experiment. This would tend to decrease the C:P ratio and be expected to encourage less fat deposition. The data did not support this possibility.

One possible explanation as to what may be occurring is that the CO supplemented diets were being used more efficiently because they contained more ME than the AF supplemented diets. Consequently, they supported more efficient growth with increased sparing of protein by energy and, therefore, improved protein synthesis. Implications to the industry are that more efficient diets tend to result in more protein and less carcass lipid storage.

Liver Yield, Moisture and Lipid Concentrations

Dietary factors have been shown to affect the level of lipids in the liver (Jensen *et al.*, 1974). Jensen *et al.* (1974) reported lower liver fat in hens from the feeding of wheat than from feeding corn. The data from this experiment (Table 5-8) tend to confirm those earlier observations. Data indicate that feeding the milo and corn based diets produced the highest liver lipid levels while triticale and wheat produced the lowest. Inspection of Table 5-2 reveals that the corn and milo diets contained the lowest total lipid levels while the wheat and triticale diets contained the highest. This would seem to indicate the possibility of a direct correlation between the liver lipid concentrations and the total dietary lipid level. The liver

TABLE 5-8
The effect of feeding corn, triticale, wheat or milo on liver moisture and lipid concentrations

Dietary grain	Fat* source	Liver		
		%Moisture**	%Lipid**	%Yield**
Corn/Soy	CO	71.69[a]	6.18[a]	3.47[a]
Corn/Soy	AF	72.60[a]	5.28[ab]	3.03[a]
Corn/Soy***	AF	72.80[a]	5.26[ab]	2.77[a]
Triticale/Soy	CO	72.31[a]	4.45[b]	2.80[a]
Triticale/Soy	AF	72.70[a]	4.37[b]	2.89[a]
Wheat/Soy	CO	73.06[a]	4.08[b]	2.89[a]
Wheat/Soy	AF	73.06[a]	5.17[ab]	2.79[a]
Milo/Soy	CO	71.44[a]	6.46[a]	2.80[a]
Milo/Soy	AF	72.39[a]	5.34[ab]	2.63[a]

* CO = Corn oil supplementation, AF = Animal fat supplementation.

** Means with different superscripts within a column are significantly different ($P \leq .05$) according to Duncan's Multiple Range Test.

*** Contains no corn gluten.

yield (calculated as the liver weight x 100 divided by the whole carcass dress weight) and the moisture levels of the livers were not different ($P \leq .05$) for the various treatments (Table 5-8). The liver moisture and lipid concentrations were affected by sex (Table 5-9). As was expected, males had the most moisture and least lipid, while the inverse relationship was true for the females.

Fat Pad Yield and Lipid Concentration

No grain related differences in fat pad weights normalized for differences in carcass weights (fat pad yield) could be detected (Table 5-10). The lipids were extracted from the fat pads and the percent lipid in the fat pad was calculated (% lipid = lipid extracted x 100 divided by the total fat pad weight) (Table 5-10). Again, no significant differences could be detected.

Fatty Acid Chromatography

The extracted lipid was methylated and chromatographed as described earlier and the fatty acid composition was determined. Table 5-10 illustrates the results of this chromatography. The data support the conclusions by Marion and Woodroof (1963), Salmon (1973), Salmon and O'Neil (1973), Bartov et al. (1974b), Webb et al. (1974), and others who suggested that the composition of the dietary fat, including the fat from the grain source as well as the supplemental fat source, can have a profound effect on the composition of the carcass fatty acids. In this experiment, the dietary C:P ratio and the fat source were held constant so that the differences in fatty acid composition observed would more nearly reflect effects of the grain source. Birds fed triticale and wheat based diets had greater

TABLE 5-9
Liver moisture and lipid concentrations by sex

Sex	% Moisture*	% Lipid*
Males	72.91[a]	4.56[a]
Females	71.89[b]	5.91[b]

* Means with different superscripts within a column are significantly different ($P \leq .05$) according to Duncan's Multiple Range Test.

TABLE 5-10
Fatty acid composition of abdominal fat
from broilers fed alternate grains

Fatty Acid	Grain Source			
	Corn*	Triticale*	Wheat*	Milo*
14:0	1.260^{b}	1.650^{a}	1.638^{a}	1.211^{b}
15:0	$.786^{ab}$	1.188^{a}	1.114^{a}	$.571^{b}$
16:0	24.410^{b}	23.496^{c}	24.177^{b}	25.177^{a}
16:1	6.997^{b}	7.324^{ab}	7.527^{a}	7.334^{ab}
18:0	7.274^{a}	7.319^{a}	7.464^{a}	7.329^{a}
18:1	42.720^{b}	44.375^{a}	43.803^{a}	43.896^{a}
18:2	15.143^{a}	12.927^{b}	12.743^{b}	12.923^{b}
18:3n6	$.492^{b}$	$.522^{a}$	$.486^{b}$	$.498^{ab}$
18:3n3	$.917^{c}$	1.235^{a}	1.148^{ab}	1.060^{b}
18:3	1.409^{d}	1.988^{a}	1.931^{b}	1.558^{c}
% Lipid	89.30^{a}	89.64^{a}	87.38^{a}	89.07^{a}
Fat pad yield	3.11^{a}	3.68^{a}	3.27^{a}	3.37^{a}

* Means with different superscripts within a row are significantly different ($P \leq .05$) according to Duncan's Multiple Range Test.

abdominal fat concentrations of the more saturated (and shorter chain length) fatty acids: 14:0 and 15:0 than did corn or milo. Palmitic acid was higher in the fat from milo fed birds than for the wheat, corn, or triticale fed birds. The lowest concentration of palmitic acid was observed in birds fed triticale based diets. Wheat based diets supported higher levels of palmitoleic acid than did corn, triticale, or milo based diets while no differences in stearic acid levels could be attributed to diet. The lack of differences between stearic acid levels was expected because stearic acid is one of the primary fatty acids which are synthesized de novo by the bird during lipogenesis (Salmon, 1973). Oleic acid levels were higher in the triticale, wheat, and milo than in the corn. Inversely, corn fed birds had significantly more linoleic acid in their fat pads than did the triticale, wheat, or milo fed birds. This agrees with the conclusions of Mickelberry et al. (1966) who demonstrated that increasing the corn oil in the diet increased linoleic acid content of the carcass at the expense of oleic and palmitic acids. The corn based diets contributed more linoleic acid (from the grain) than did the triticale, wheat, or milo diets. The 18:3n6 fatty acid shown is an ante-iso isomer of linolenic acid which is present in animal fat. The higher levels of the 18:3n6 isomer in fat pads from the triticale fed birds probably reflects the high AF supplementation level in the triticale based diet (Table 5-2). The 18:3n3 is the common form of linolenic acid and was present in the least concentrations in fat pads from birds fed corn based diets followed by the milo, wheat, and triticale diets. The total linolenic acid levels were significantly

different ($P \leq .05$) for all the dietary treatments. The lowest concentration of linolenic acid in fat pads was produced by feeding the corn based diet, followed by milo, wheat, and triticale. When the fatty acids were arranged into four groups according to the nature of their saturation or unsaturation (Table 5-11), it became apparent that the corn based diets supported the deposit of abdominal fat with less saturated and monounsaturated fatty acids and more polyunsaturated fatty acids than did the triticale, wheat or milo based diets. This indicated that the alternate grain based diets produced carcasses which had lower levels of polyunsaturation in the abdominal fat than did the corn control diets. This has considerable economic importance to the producer because it means that the alternate grains tested in this study can be substituted for corn in broiler diets without increasing the probability of carcass spoilage through lipid oxidation and without lowering the melting point of the carcass lipids.

TABLE 5-11
Dietary effect on fatty acid composition
of abdominal fat

Diet Grain	Type of abdominal fat			
	Saturated	Mono-unsaturated	Poly-unsaturated	Total unsaturated
Corn	33.73	49.72	16.55	66.27
Triticale	34.35	51.70	14.92	66.61
Wheat	34.39	51.33	14.72	66.05
Milo	34.29	51.23	14.48	65.71

CHAPTER VI
SUMMARY AND CONCLUSIONS

Considerable research with previously developed varieties of small grains has already been published. However, the results and interpretations presented in this dissertation reveal information about newly introduced cultivars of wheat, triticale, and bird resistant milo which have not been published.

The primary objective of these studies was to determine the feeding values of new varieties of alternate cereal grains which grow well in the Southeastern states and which could potentially reduce the grain deficit in those states.

In the first series of experiments, the caloric density of the diets was increased to 3200 Kcal ME/Kg from the 3124 Kcal ME/Kg formerly used by Marion et al. (1984) who observed suboptimal growth with birds fed triticale based diets. In the current series of experiments, birds fed triticale based diets were generally more efficient than those fed wheat or corn but tended to reduce their feed intake. When the caloric density was adequate (3200 Kcal ME/Kg), the birds apparently consumed enough energy (when protein and amino acids were adequate) even at the reduced intake levels, to support optimum growth. Florida 301 and 302 wheat and Pioneer 304C tropical corn did not depress intake levels and also supported optimum growth when 3200 Kcal ME/Kg were provided.

The second series of studies investigated the influence of protein concentration (density), triticale substitution levels, diet density (bulk), and vitamin density on the performance of birds fed triticale based diets. This series of experiments directly addressed the influence of these factors on the rate of growth with the feeding of triticale. In the first experiment, four substitution levels of triticale were tested in diets containing 23 or 21% protein. Birds fed triticale based diets were again more efficient than the corn based diets. Substitution level was apparently not important, but the inclusion of 23% protein was necessary for optimum growth with the triticale based diets. The higher protein level apparently provided the protein density necessary for optimum growth when intake is reduced by the feeding of triticale. The data suggested the possibility that in triticale based diets supplemented with lysine but containing only 21% protein, threonine may become limiting. In the second experiment, the influence of dietary density (bulk) on the performance of birds fed triticale based diets was determined. Two treatments (pelleting and feed restriction) designed to reduce the effect of differences in feed density were used to determine the interaction between diet density and the performance of birds fed triticale based diets. The triticale supported growth rates comparable, but not superior, to corn when dietary intakes were restricted. No improvements in growth rate were observed from the pelleting of triticale. These data rule out the possibility that dietary density (bulk) is solely responsible for the reduced performance sometimes observed from the feeding of triticale based

diets. The third experiment was designed to determine if the vitamin-mineral premix commonly used at the University of Florida might be limiting (at the lower intake levels common in feeding triticale based diets) in certain micronutrients which could be adequately provided by a standard vitamin-mineral premix normally formulated to meet the needs of turkeys. It was concluded that the vitamin density of the feed containing the "chicken vitamin-mineral premix" was adequate to support maximum growth.

A third project was designed to evaluate the performance of birds fed corn, triticale, wheat, or milo based diets supplemented with either corn oil or animal fat. The experiment extended over a longer period of time (49 days) under environmental conditions more closely simulating commercial broiler production facilities. Triticale based diets supported a rate of growth which was comparable to corn based diets but was not as rapid as for the wheat or milo based diets. In general, the corn oil supplemented diets supported better efficiency than did the animal fat supplemented diets. It can be speculated that the actual energy value of the animal fat was below the 3750 Kcal ME/Kg table value used to formulate the feed and the result was a diet with insufficient caloric density.

The second phase of this project involved the evaluation of the effect of feeding alternate grain based diets on several carcass quality and compositional factors. Cooked carcasses from birds fed corn, triticale, wheat, or milo were evaluated by sensory panelists who did not detect any differences between the flavor of carcasses from birds fed the different grain sources and those fed corn based

diets. Each of the different grains produced different shank pigmentation values. Corn based diets with corn gluten meal produced the most highly pigmented shanks and triticale fed birds produced the least pigmented shanks. Supplemental pigment sources will have to be added to wheat, milo or triticale based diets when more highly pigmented skin in broilers is preferred. Dietary grain source was not correlated with carcass dressing yield, fat pad yield, fat pad lipid level, or liver yield. However, the use of supplemental corn oil tended to produce carcasses which had higher protein levels than observed from the supplementation of animal fat. Birds fed corn and triticale based diets supplemented with corn oil produced carcasses with higher protein levels than did the wheat or milo based diets. Birds fed milo based diets had higher carcass lipid levels. Dietary factors were shown to affect the liver lipid levels. Corn and milo fed birds had the highest liver lipid levels while triticale and wheat produced the lowest. This liver lipid level correlated well with the actual dietary lipid intake. Fatty acid chromatography of abdominal fat pads, from birds fed corn, triticale, wheat, or milo based diets supplemented with animal fat, confirmed the correlation between dietary grain and abdominal fat composition. The fatty acid composition of the carcass fat is of economic importance to the poultry processor. Carcass fats with higher levels of unsaturated fatty acids are more susceptible to oxidation and have lower melting points which can degrade the value of the carcass. Data from this experiment indicate that birds fed triticale, wheat, and milo based diets produced higher abdominal fat concentrations of the saturated and

monounsaturated fatty acids than did corn fed birds, which had higher levels of the polyunsaturated fatty acids in their fat pads. These data are important to the producer because they indicate that when alternate grains are substituted for corn in the diets of broilers, the resulting fatty acids in the carcasses should be no more susceptible to lipid oxidation than those that would be produced by corn based diets.

The data from this entire project indicate that alternate grains can be effectively substituted for corn at all levels when diets are provided with adequate energy density (3200 Kcal ME/Kg) and protein density (23% protein). Proper caloric density seems to be especially critical to the performance of birds fed triticale based diets. Diet density (bulk) is apparently not limiting with triticale based diets. Grain source does affect the carcass proximate and the fatty acid composition but broilers can be fed alternate grain based diets without adversely affecting the flavor or lipid stability of the resulting carcasses.

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BIOGRAPHICAL SKETCH

The author, Dean E. Bell, was born April 18, 1948, at Miami, Florida. He received his Eagle Scout Award in 1965. Dean was elected Senior Class Treasurer in 1965 and graduated ninth in his class at Boca Raton High School in 1966. He entered Palm Beach Junior College in the fall of that year and received a Kiwanis scholarship in 1966 and again in 1967. The author received his Associate of Arts degree in 1968 from Palm Beach Junior College and entered the University of Florida where he obtained a Bachelor of Science degree in agriculture in the fall of 1971. As an undergraduate, the author remained active as an assistant leader in the Boy Scouts of America and participated as a member of the Alpha Zeta honor fraternity.

The author entered the Graduate School of the University of Florida in the fall of 1973 and was granted the degree of Master of Science in Education in the spring of 1975. He taught vocational agriculture and science and operated a professional protrait and wedding studio in Okeechobee, Florida, from 1975-1983.

Dean then entered the University of Florida in the fall of 1983 and was awarded the SEPEA Tuco/Upjohn Scholarship in 1985. He was also inducted into the Gamma Sigma Delta Honor Society in 1985. Dean was awarded a meritorious paper award from the Florida Academy of Sciences in 1985 and presided over the University of Florida poultry science club during 1985 and 1986.

The author married the former Mary H. Houghton and they presently have a 10-year-old daughter, Heather; an 8-year-old daughter, Laurel; a 7-year-old daughter, Miranda; and a 4-year-old son, Jeremy.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

James E. Marion

James E. Marion, Chairman
Professor of Animal Science

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